I.L. 43-510

Type PA Universal Oscillograph

INSTRUCTION BOOK

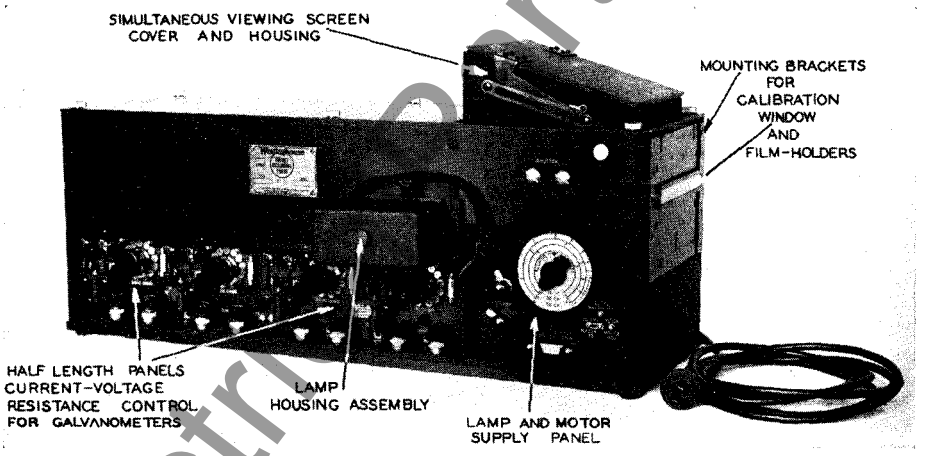

FIG. 1—GENERAL VIEW OF THE PA UNIVERSAL OSCILLOGRAPH COMPLETE WITHOUT FILMHOLDER BUT WITH SIMULTANEOUS VIEWING AND CONTROL PANELS FOR LABORATORY APPLICATIONS.

Westinghouse Electric & Manufacturing Company

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Westinghouse

Type PA Universal Oscillograph

INSTRUCTIONS

INTRODUCTION

General

The Type PA oscillograph is a mechanically operated electro-magnetic instrument which measures so-called instantaneous electrical quantities as a function of time, either visually, or photographically. The type PA oscillograph measures quantities throughout a frequency range of from zero or continuous quantity to a frequency slightly more than 10,000 cycles per second.

The PA universal oscillograph, Figs. 1 and 2, is designed to cover the entire oscillograph field as required by the general user and do it at a minimum investment. It is equally applicable to the **laboratory** for special and routine studies, to exhibit instantaneous variables in the classroom, or to **automatic recording of power system faults.** The main case with the light source, optical system and means to mount any accessories is the same, regardless of the application. Therefore, starting with the main case, the customer may choose just those parts he needs which can be mounted on the main case and which will be the oscillograph he desired for his purpose.

The following are a few of the outstanding features found in the PA universal oscillograph:

1. Simultaneous viewing while photographing.

2. A complete line of oil-seepage proof galvanometers which are interchangeable for all applications and with elements capable of being adjusted independently of the magnet-well.

3. Complete line of control panels, any of which can be mounted within the main case.

4. Simultaneous viewing mechanism capable of being synchronized on any frequency.

5. The fundamental part of the oscillograph for all applications is the same. It is only necessary to change the panels to suit requirements.

6. Complete line of filmholders with integral-mounted, wide-range, adjustable-speed motors.

7. The complete unit is unusually small and compact.

8. A simplified and efficient optical system which will use any of a choice of three cheap universal lamps—namely, the single filament 6-8 volt automobile lamp of either 21, 32 or 50 candle power.

9. Complete line of fuses for galvanometer protection.

10. Lastly, the above features are incorporated into one unit, resulting in a maximum of utility, flexibility, and accessibility.

Unpacking

The oscillograph is shipped in a heavy, one inch, wood case with felt-padded braces to hold the instrument in a definite position within the shipping case, which has sturdy luggage handles on either end for convenience as a carrying case.

Unpack the oscillograph by removing all the wood screws from the cover of the shipping case. Also, remove the top braces and packing. The oscillograph can then be extracted vertically by two cloth lifting-straps.

The oscillograph, as received, has its internal connections made and the galvanometers filled with the proper damping fluid ready for service. To put the oscillograph into operation there remains only the external connections to be made. **However, before connecting in the instrument, thoroughly read the instructions on all parts supplied so as to avoid mistakes and to obtain best results.**

The oscillograph may be operated most satisfactorily by placing it on a small, flat-top table, either stationary or portable. The approximate dimensions of this operating table found to be most convenient are 36 inches long, 25 inches wide, and about 39 inches from the floor to the table top. A mobile steel table S#930416, specially constructed for this oscillograph, is available. This table is mounted on rubber wheels, has totally enclosed compartments underneath for storing all parts and a flat linoleum top with a sturdy handle on one end for pushing the table from place to place.

MAIN CASE

The main case, S#877036 for 4 elements or S#1009701 for 7 elements Figs. 4 and 5, is the common part of the PA line of oscillographs. It either houses or has means to mount any oscillograph accessory. The top level of the case consists of the fundamental or oscillograph proper. In this compartment is the complete optical system with the galvanometers. The lower level of the case is the space for mounting of the control panels for the galvanometer as well as the control of the operations of the oscillograph such as the lamp, filmholders and simultaneous viewing attachment. On the outside of the case are the mountings for the filmholder, lamp and polygon motor, and neon timer.

Optical Compartment

a. General

The optical compartment, Figs. 2 and 6, starts with the light source which is mounted externally on the left-hand side of the case. The light from the source is directed through a corrected compound lens mounted on the inside of the case wall, hence onto a group of adjustable prisms positioned in a row. The prisms reflect the light ninety degrees through a group of adjustable slits to the galvanometers placed at the rear of the main case. The light enters the galvanometer through the lens-window and is reflected by the mirror back out the same lens-window to the viewing screen and photographic surface.

The focal length of the galvanometer lens window is selected to focus the luminous image of the adjustable slits onto the viewing screen and the film surface. The top part of the slit image is used for photographing and the bottom part of the image is reflected to the viewing screen. This condition is reversed when using the cover with calibration window or the four-sided polygon. In either case the film surface and the viewing screen are equidistant from the galvanometers, purposely designed to give correct calibration of the photographed beam by measuring the beam deflection on the viewing screen.

b. Lamp Assembly

The complete lamp assembly on the left side of the main case, Figs. 5 and 7, is mounted similarly to the filmholders by sliding vertically in grooved brackets shown in Fig. 4. The lamp compartment is assembled on three plates with thumb screws to give universal adjustment of the lamp in one plane. The vertical motion is made by top thumb screws, and the horizontal motion is made by turning the side thumb screw. The lamp is set in the middle of the horizontal travel by loosening the lamp socket set screw and sliding the socket in or out of its holder. The socket is tightened in a position to place the vee filament in a horizontal plane.

The lamp housing cover is removed by loosening a single thumb screw on top of the cover housing. When a new lamp is put in, the only adjustment which is necessary in the optical system is positioning the lamp by turning the horizontal and vertical adjustment screws until the images from the slits fall back on the galvanometer lens-windows.

When the oscillograph is being used for automatic operation to photograph chance disturbances, the lamps should be renewed at least every month or better still every three weeks. In this application the lamp is kept at a pre-heat value continually so that the lamp will come to photographic brilliancy quickly. (See discussion under Automatic Panel).

c. Optical Box

The optical box, Figs. 2, 5, and 6, is placed on the inside middle of the main case. Two small covers on either end of

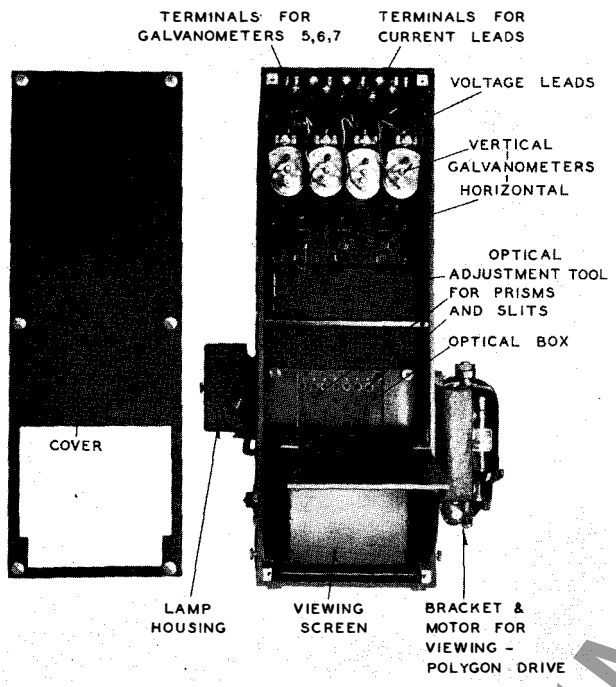


FIG. 2—TOP VIEW OF THE PA UNIVERSAL OSCILLOGRAPH WITH COVER REMOVED TO SHOW THE ACCESSIBILITY TO INTERNAL PARTS.

the optical box may be removed by taking off two thumb nuts on each cover. Under the right-hand cover is a circled-cross or target engraved on the oscillograph wall. The position of the lamp assembly is adjusted to center the light spot on this target by adjusting the horizontal and vertical lamp adjustments, until the lamp is in the mean or middle position for intended motion in either direction.

On the left-end of the optical box under the other small cover is the compound lens. The focus of the light on the galvanometers is made by turning this lens in or out of its holder until the image of the lamp filament is sharp, as seen on a sheet of white paper in the plane of the galvanometers. The recommended focus is to adjust the image to be sharply in focus at the middle section of the galvanometer bank. That is, the corresponding galvanometers on either side of the oscillograph center line should have the spots equally focused.

The prisms, Fig. 6, which reflect the light on the galvanometers, are mounted on the end of a shaft which is hinged from a ball and socket joint. This universal hinging allows a wide adjustment in the placing of the light spot. The hinge is sufficiently tight to hold the prism in adjustment for any ordinary handling of the instrument. All adjustments are made at the factory and they should still be in adjustment upon receipt of shipment of the instrument. A special optical adjustment tool, Fig. 2, or center-pin screw-driver is supplied to adjust the prisms and slits. This tool is carried in a clamp near the optical box and should be kept there when not in use.

The adjustment of the light spots can best be made by holding a piece of thin white paper in a position near the optical box and just low enough to receive the images from the galvanometers only. Then while watching these spots, adjust the prisms and lamp positions until a **uniform bright slit reflection appears from all galvanometers.**

SIMULTANEOUS VIEWING

The simultaneous viewing attachment, shown in Figs. 1, 2, 3 and 6, is simplified in its design to the extent that it is handled as an accessory to the oscillograph. It may or may not be supplied with the oscillograph as desired. This attachment may readily be removed or added. The mounting holes may be closed by means of screws and plug parts.

The simultaneous viewing attachment consists of the following: Within the case is the cylindrical condensing lens and its mountings, and the polygon assembly with its ball-bearing mountings, see Figs. 4, 5 and 6. On top of the case is the viewing screen, the casing housing and the light shielding cover and reflecting mirror and on the side of the main case and adjustable-speed polygon-drive motor and motor mounting bracket, see Fig. 2.

The light beams from the galvanometers are adjusted so that the lower half of the beam is intercepted by the first viewing condensing lens Fig. 6. This condensing lens concentrates the light on to the twelve-sided polygon. Any two polygon mirror surfaces will reflect two light beam spots so that they may fall on the opposite ends of the viewing screen and be visible at a single glance. This feature of always having a recording beam on the screen has the big advantage that no other oscillograph in the past has had and that is to always have the record in sight and miss no part of it. In case of any transient motion of the beam, it will always be visible on the screen somewhere.

Any continuous phenomena may be viewed at several different wave lengths by setting the motor at the proper speed. The motor speed is adjusted by merely turning the knurled knob opposite the

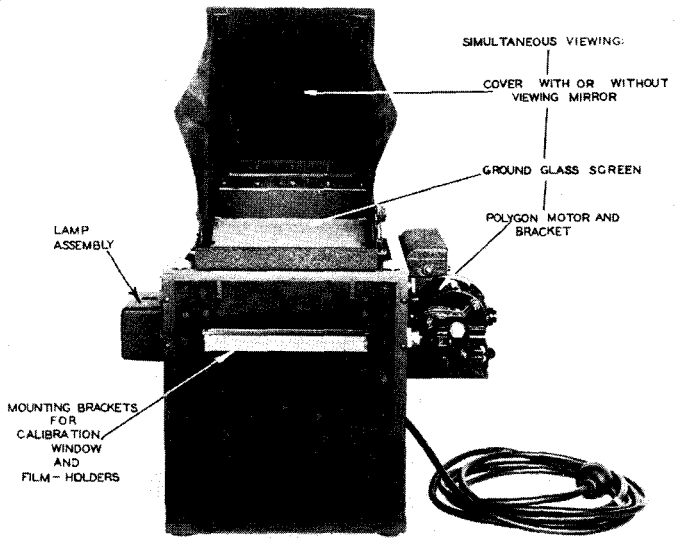


FIG. 3—FRONT VIEW OF THE PA UNIVERSAL OSCILLOGRAPH WITH SIMULTANEOUS VIEWING COVER OPEN.

drive end of the motor. The turning of this knob on the motor shaft sets the speed control governor contacts for a constant speed.

Caution should be used to not have direct light shining from an external source on the viewing screen while photographing. Naturally, the darker the surrounding room the more visible becomes the record on the viewing screen. While the oscillograph is not in use, it is well to keep the cover closed over the viewing screen if for no other reason than to keep dust settlings off the screen. To clean the screen use water with a little hand-soap if necessary. **Do not use a cleaning fluid of any sort on the viewing screen, as it may remove the ground surface.**

If the lid covering the ground screen is supplied with a five-inch square mirror, additional viewing may be obtained. By raising the cover and tightening the lid braces at such an angle so that groups seated in a class-room or lecture room may all view the record on the screen at once.

The motor drive is mounted on an absorption cushion to avoid transmission of motor vibration to the galvanometers. If the motor mounting screws are screwed too tightly, this cushion mounting becomes ineffective. **Always keep motor mounting screws as loose as practicable.** These screws also are the means of keeping the motor shaft axis at 90° to the polygon axis. Care should be taken to see that this condition exists.

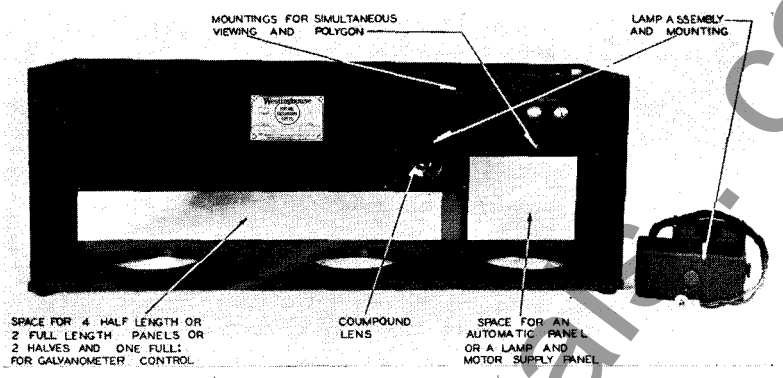


FIG. 4—SIDE VIEW OF THE MAIN CASE; THE COMMON PART OF THE PA UNIVERSAL OSCILLOGRAPH LINE.

To improve the quality of the viewing record it may also be necessary to adjust the position motor mounting bracket to give better alignment of the motor with the polygon shaft. This bracket is mounted at three points and has clearance holes in the casting to allow for adjustment in the shaft alignment. The motor shaft is merely pushed into the flexible coupling made of a combination of rubber and metal. This coupling is not critical to alignment and will tolerate a considerable misalignment before it will effect the synchronization of the viewing record.

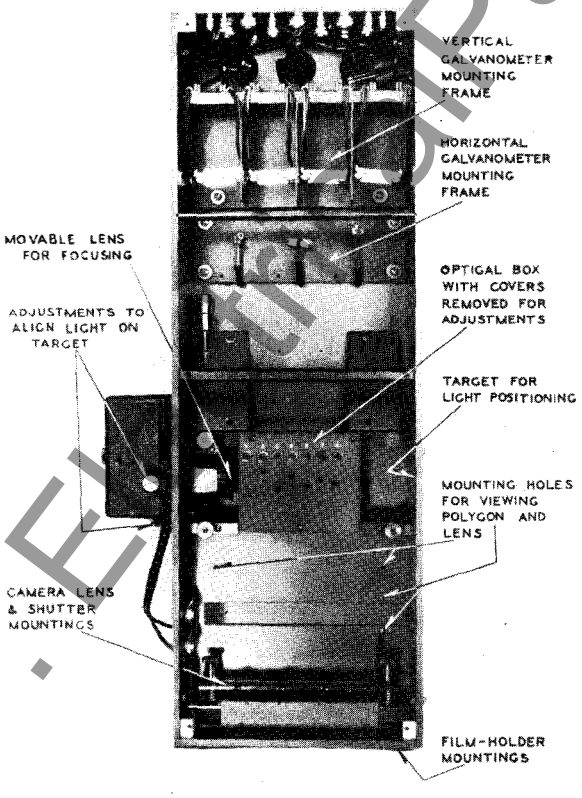


FIG. 5—TOP VIEW OF THE MAIN CASE SHOWING THE MOUNTING LOCATIONS OF OSCILLOGRAPH ACCESSORIES.

GALVANOMETERS

General

The so-called mechanical or electromagnetic oscillograph is built around a modified d'Arsonval or a one turn moving-coil galvanometer often referred to as the Duddell or bifilar type. The complete vertical galvanometer, Fig. 8, or complete horizontal galvanometer Fig. 10 consist essentially of two major parts; namely, the vibrator or element, and the magnet well. The vibrator has a single loop of thin, flat silver strip, with its ends soldered to two binding posts and the loop stretched over two ivory bridges to an insulated pulley mechanically attached to a tension spiral-spring. The strips between the ivory bridges are parallel with a small mirror cemented across the strips at their mid-portion. The magnet well contains the mounting for the vibrator, the magnetic field structure, and the oil bath for damping the vibrator strips or element. This type is used for current or voltage measurements. Use of the principles involved has produced a line of instantaneous and average value watt galvanometers Figs. 23, 25, 29 and also one of the permanent magnet moving vane type Fig. 31.

The galvanometer places 1, 2, 3, 4, Figs. 2, and 6, are of the vertical type Figs. 8, 23, 25, 29, 31, whereas for places 5, 6, 7, Figs. 2, 6 they are of the horizontal type, Fig. 10. In the former the vibrator is removable and rotatable with respect to the magnet poles. The tension spring is adjustable. In the latter the vibrator is part of the well top plate. It is not removable or adjustable with respect to the magnet poles except for repairs. In early types its spring tension is fixed. More recent models have an adjustable spring. The vertical type vibrators can be obtained separately whereas in the horizontal type the vibrator comes as part of the complete galvanometer.

Unpacking

When galvanometers are shipped, assembled in an oscillograph, they are filled with damping fluid and the mirror beam-reflections are focused ready for service. It is always wise to inspect the galvanometers carefully for any breakage in shipment or oil leakage that

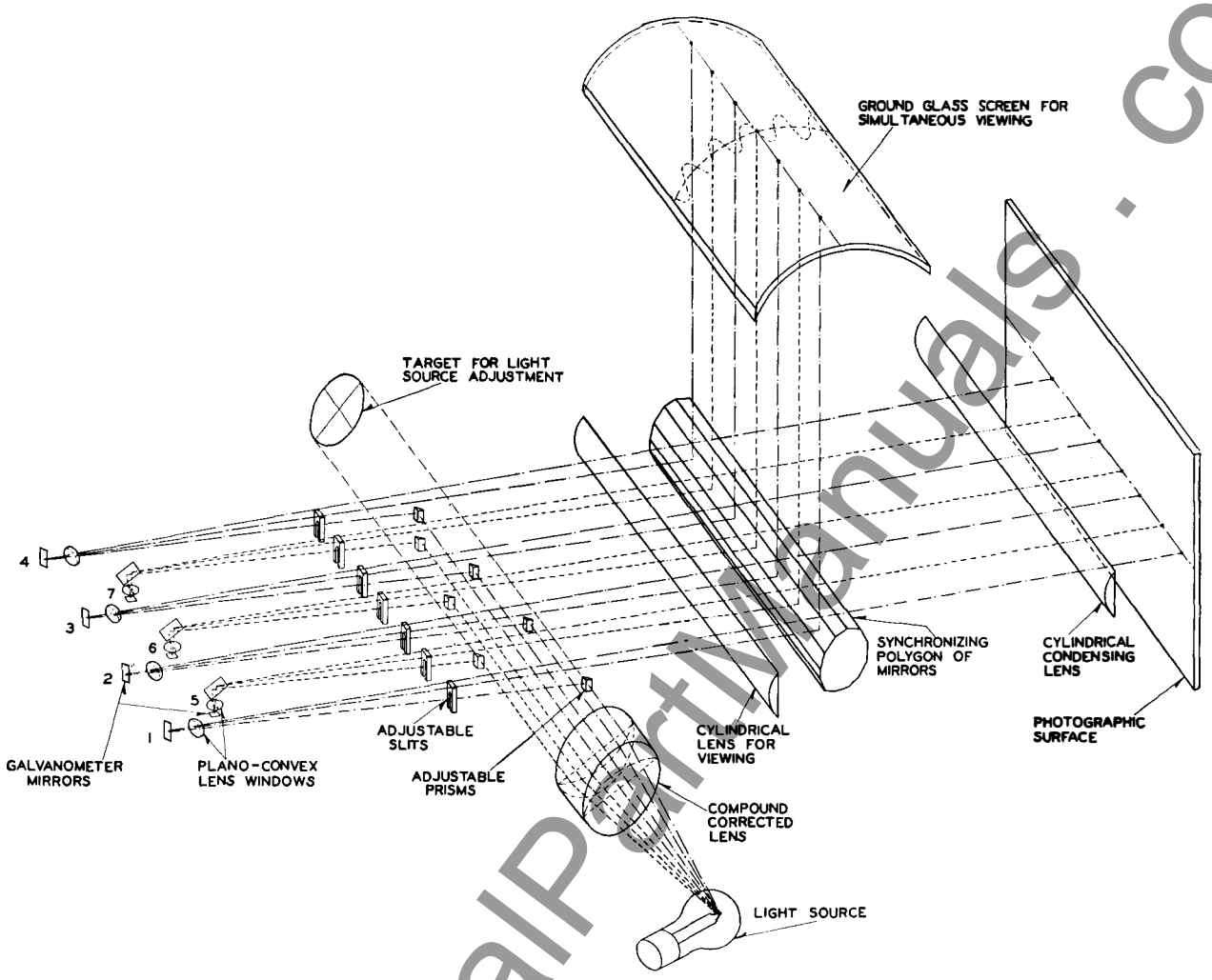


FIG. 6—DIAGRAMMATIC SKETCH OF THE OPTICAL SYSTEM FOR THE PA UNIVERSAL OSCILLOGRAPH

may be due to some mechanical flaw, but do not remove vibrator from well before completely testing the galvanometer.

If the vertical vibrators are shipped under separate cover, turn the holding bracket of the carrying case to one side and remove the vibrator by lifting it vertically, being careful not to strike the side of the case while withdrawing. Remove the center thumb screw from the vibrator and fill the well with the proper damping fluid (see table, Fig. 9, for the correct fluid) to $\frac{3}{8}$ inch of top plate, as shown in Fig. 8, and read under "Galvanometer Maintenance" the paragraph on "Vibrator and Well Oil Sealing" before inserting the vibrator into the magnet-well. With the small mirror toward the front of the galvanometer, lower the vibrator stem into the well until the vibrator rests on the top plate of the well, see Fig. 33. Next slide the vibrator forward until the vibrator frame rests against the outer rim of the top plate. At the same time view through the lens window to see that the element goes in the air gap and does not bump the pole faces on either side of the air gap. Then place the center holding screw and turn screw in good and tight by hand, using a cloth between thumb and finger to obtain additional turning effect, but **do not use pliers.** The pinion adjustment screw is then put in the small hole in the top plate near the pinion rack.

Description

Figs. 8, 10 show the side view of a center line cross-section, cut from front to back, of a complete permanent magnet galvanometer of the vertical and horizontal type. These figures show the element strips suspended between the two bridges (span $\frac{1}{2}$ inch apart in this particular case) and placed in a powerful magnetic field set up by a specially designed magnet of high coercive force steel. The sensitivity and period of the elements are varied by adjusting the following: cross-sectional area of the strips; the distance between bridge supports; and, the spring pull on the strips.

The table in Fig. 9 lists the complete line of galvanometer characteristics showing their sensitivity, the element and field resistances, the resonant frequency, the element safe carrying current and the styles of the vibrator with the proper element fuse and damping fluid. The first seven items are interchangeable in the same permanent magnet-well having a black moldarta case Fig. 8. The twin vibrator (item 8), Fig. 9, has a similar permanent magnet-well except it has a wider air gap. Items 9 to 13, Fig. 9, inclusive fit in a regular square die-cast well Figs. 23, 25, 29 and 31 and all have electromagnet field structures. These magnet-wells are each made special for its corresponding vibrators with the exception of items 10 and 11 which have a common electromagnet well. These take vibrators items 2 and 3 respectively. Items 14 to 17 inclusive Fig. 10 are of the horizontal type in which the vibrator assembly forms a cover plate for a moldarta well thus making the complete galvonometer.

When vibrators are changed from one magnet-well to another **it must be remembered to change the damping fluid in the well to correspond with the new vibrator.** The **fuse** must **also** be **changed** to protect the new vibrator. For the correct damping fluid and fuse see Fig. 9 and the discussion under vibrator being used.

The approximate response curves for the galvanometers are also given for most of the elements. These curves show the percentage response with varying frequency and are taken by holding a constant input to the galvanometers, throughout a wide range of frequency and measuring the deflection of the galvanometer beam on the calibration window for each frequency setting. In taking a response curve a reliable sine wave frequency source should be used, which can be varied throughout the range of the vibrator, also an indicating instrument calibrated in current in the galvanometer circuit which responds accurately, independent of the frequency range covered. The shape of the curve depends a great deal on the damping fluid used and somewhat on the temperature. The direct current reading of the constant input is taken as 100%.

Operation

The galvanometers are filled with the proper damping fluid before shipment and are ready for service as received. They can be connected directly into the circuit but before applying the voltage the proper circuit fuse to protect the galvanometer should be checked. Also, enough resistance should be in the circuit so that by applying Ohm's Law (E = RI) the circuit current will not exceed the "safe continuous element current" as listed in the table of characteristics, Fig. 9. The values in the above equation are: E equals the applied line voltage, R the total circuit resistance including leads, fuse and panel resistance, and I the current through the vibrator.

Referring to Fig. 6 it is seen that elements 5, 6, 7 are between elements 1 & 2, 2 & 3, 3 & 4 in the order mentioned. Each horizontal element is equipped with an adjustable reflecting mirror which not only bends the light source beam at right angles to the vibrator mirror but also permits the beam to be placed anywhere on the viewing screen or film. Fig. 6 shows the paths of the beams of light from the source (the illuminated slit) to the vibrator mirrors and back to the viewing screen and the photographing surface. These beams may be checked for correct position by tracing the paths of light with a piece of white paper.

It should be noted that when elements 5 and 7 are used in conjunction with elements 1 and 4 that the reflected beams of light from 1 and 4 are usable only over approximately 75% of the full film width of 5 inches. This is due to the fact that the beams from 1 & 4 for greater excursions will intercept the mirror assembly on top of elements 5 and 7. Therefore when using this arrangement care should be taken to place phenomena which will exceed these excursion limits on elements 2, 3, 5, 6, 7 where this interference does not occur.

Under actual operating conditions it

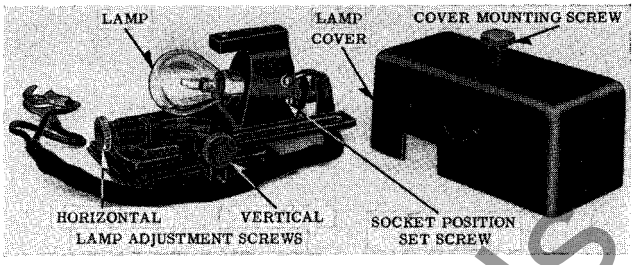


Fig. 7—Lamp-Housing Assembly with Cover Removed to Show Internal Parts.

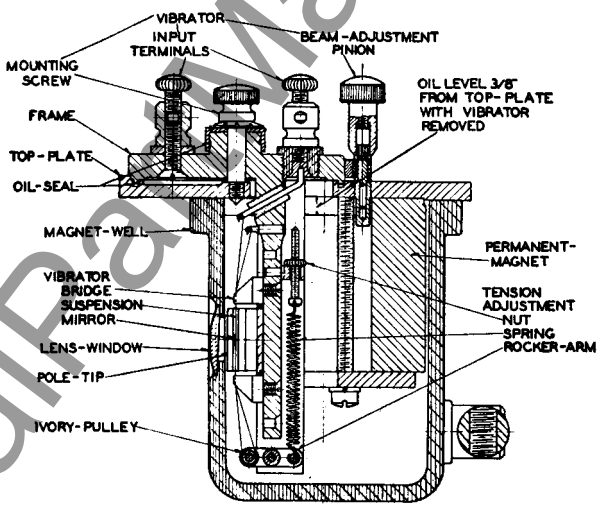


Fig. 8—Center-Line Cross-Sectional View of the Standard Vertical Permanent Magnet Vertical Galvanometer.

GALVANOMETER CHARACTERISTICS—TYPE PA UNIVERSAL OSCILLOGRAPH

Approximate Sensitivity When Damped

Item	Type of Galvanometer	Sensitivity Amps./In. D-C. ✣		Vib. Res. in Ohms	Vib. Sprg. Ten° in Oz.	Field Coil Res. Ohms	Un-damped Freq. ∅ Cy./Sec.	Safe Cont. Element Current	Vibrator Style No.	Fuse Style No.	Damping Fluids (8 Oz. Bottles) Style No.
1	Standard Vertical	.150	A	0.8	6	per mag.	6000	.45 A	492 484	719 554	723 979
2	Sensitive Vertical	.025	A	1.5	4	per mag.	3000	.30 A	492 485	719 555	723 978
3	Sen. Fin. Vertical	.025	A	1.5	4	per mag.	Damped	.30 A	565 161	719 555	723 978
4	High-Sen. Vertical	.0065	A	5.5	⅓	per mag.	3500	.13 A	577 707	719 556	723 980
5	Super-Sen. Vertical	.0023	A	5.5	⅓	per mag.	1500	.13 A	577 706	719 556	724 622
6	Super-Fin. Vertical	.0023	A	5.5	⅓	per mag.	Damped	.13 A	877 488	719 556	724 622
7	High Frequency Vertical	.285	A	2.2	9	per mag.	10000	.30 A	877 443	719 555	934 154
8	Twin Vib. Vertical	.0425	A	1.5	8	per mag.	3000	.30 A	573 785	719 555	723 978
9	Ultra-Sen. Vertical	.000075	A	...	2	20000@	700	.010 A	877 494	not fsd.	723 978
10	1 Phase Inst. Watt Vertical	.57	A^2	1.5	4	0.022§	3000	.30 A	492 485	719 555	723 978
11	1 Phase Avg. Watt Vertical	.60	A^2	1.5	4	0.022§	Damped	.30 A	565 161	719 555	723 978
12	Polyphase Inst. Watt Vertical	1.50¢	A^2	0.7	4	0.019*§	2500	.30 A	560 677	719 555	723 978
13	Polyphase Avg. Watt Vertical	0.37¢	A^2	2.4	2	0.009*§	Damped	.45 A	652 256	719 554	723 978
14	Standard Horizontal	.150	A	0.6	6	per mag.	6000	.45 A	1 001 995†	719 554	723 979
15	Sensitive Horizontal	.030	A	1.1	1¾	per mag.	4000	.30 A	1 001 996†	719 555	723 979
16	High-Sen. Horizontal	.0065	A	3.9	⅓	per mag.	3500	.13 A	1 001 997†	719 556	723 980
17	High-Freq. Horizontal	.285	A	2.2	9	per mag.	10000	.30 A	1 001 998†	719 554	934 154

† Style for horizontal types are for Galvanometer complete.
∅ For apparent damped resonance, multiply by 0.58. (See Bibliography No. 3)
@ Inductance 45 henries.
* Resistance per Coil.
✣ 20" Optical Lever.
¢ Sensitivity per Coil.
§ Inductance per Coil at 5 amperes in milli-henries.
Items: 10 and 11 = .172; 12 = .162; 13 = .046.

Fig. 9

may be desirable that all galvanometer beams be focused on the photographic surface in the exact same plane. This is shown by the horizontal line on the photographic surface Fig. 6. This adjustment is made at the factory as close as visual inspection will permit. For more exact settings a photographic trace must be made with all elements connected in series to a direct current source. On make or interruption of the source the exact plane of each element can be determined by noting the point on the film where each galvanometer excursion begins. Any differences may be compensated by placing shims between the bracket and the galvanometer mounting base for the vertical units and between the galvanometer well and the mounting base plate for the horizontal units. Differences in this condition of beam focus are due to the vibrator mirrors not being in the same optical plane i.e. in the center of the vibrator bridge supports (see notes under galvanometer maintenance). Corrections will not be present on the viewing screen due to the interposed polygon reflecting surfaces.

Calibration

After the connections are all made and the desired beam deflection on the calibration window is obtained, a low-reading milliammeter should be inserted in series with the galvanometer and the current read, at the same time a careful measurement of the beam deflection on the calibration window is taken in inches. Then the ratio of the d-c current in amperes to the beam deflection in inches is the sensitivity of the galvanometer. If alternating sine wave current is used, the deflection overall peak-to-peak measurement will be 2.83 times the d-c. deflection (or sensitivity) for the same current reading (effective value). See Figs. 22B and 23A. In the case of the watt-galvanometers, the sensitivity is the product of the direct current in one field coil by the direct current in the corresponding element coil divided by the beam deflection on the calibration window. Unless the current is very steady, it is advisable to read the circuit currents and beam deflection simultaneously. If the current is very steady and it is a continuous phenomena, the meter can be left in the circuit while photographing and the beam deflection measured more accurately on the film. On many transitory currents the indicating meter, if left in the circuit, may give regenerative currents and give an erroneous beam trace on the oscillogram. Therefore, for careful work, it is advisable to remove the meter from all galvanometer circuits before the test, to use the same leads in each circuit during the test and to check calibration after completion of the test.

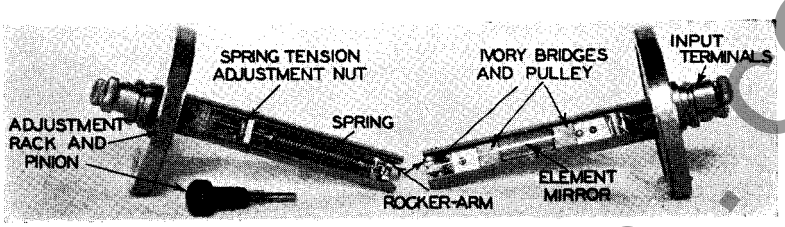


FIG. 11—BACK AND FRONT VIEWS OF THE STANDARD VIBRATOR REMOVED FROM THE MAGNET-WELL.

Permanent Magnet Galvanometers

The standard vibrator is more commonly used than any other element due to the fact that it covers the widest field of any of the vibrator line. This is because it has the largest mirror and lowest resistance with a wide frequency range of all elements. It is known as a general purpose vibrator finding its use mostly in laboratory tests of commercial apparatus.

In recent years because of demands for greater sensitivity, such elements as the sensitive, which is also used in the instantaneous watt galvanometers, the high-sensitive, and super-sensitive are finding a much more extensive use. Special elements such as the high-frequency which is used mostly for sound analysis, and the ultra-sensitive or Legg type, which is used for extremely small currents of line frequency, were developed primarily to extend the upper and lower range of the oscillograph field. These find their greatest use in problems of research. For further details see the headings below. Unless differences are noted the discussion applies equally well to vertical and horizontal types.

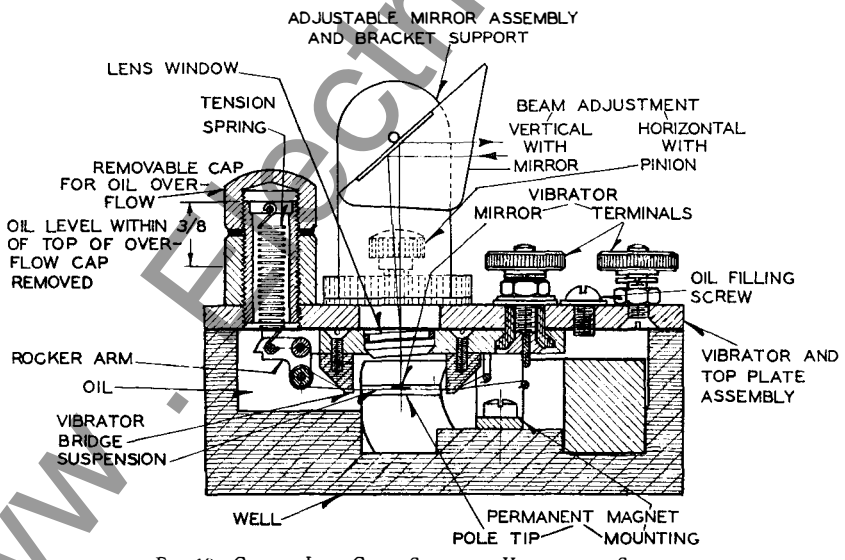


FIG. 10—CENTER-LINE CROSS SECTIONAL VIEW OF THE STANDARD HORIZONTAL PERMANENT MAGNET GALVANOMETER

High Frequency Vibrator

The characteristics of the high frequency vibrator are shown in Fig. 12. This vibrator is particularly adaptable for voltage and current measurements within the frequency range of the audio-spectrum. Corrections for response in the range up to 5000 cycles are negligible. Beyond that range curve Fig. 12 should be used.

The precautions which apply to temperature variations and current carrying capacity as given for the standard vibrator are equally applicable to the high frequency vibrator. Also see Fig. 18.

The vibrator resistance is 2.2 ohms for the vertical type and 1.6 ohms for the horizontal type. Its d-c. sensitivity is 285 milliamperes per inch. Used with the standard shunt of ¼ volt output a series resistance of 2¼ to 2½ ohms will give one inch overall alternating current deflection on film or screen. For the same deflection on a-c. voltage peak-to-peak, a series resistance is added of 10 ohms per volt or 1200 ohms for 120 volts r.m.s.

Standard Vibrator

The characteristics of the standard vibrator are shown in Figs. 9, 11 and 13. This vibrator, Fig. 11, is particularly adaptable for current and voltage indications and for frequencies below 4000 cycles per second, although it will give a 22 per cent response at 10,000 cycles. Although Fig. 13 indicates a temperature of 20°C. for the response curve, wide changes of temperature may be tolerated without much effect in the frequency range of zero to 1500 cycles. In this range it has a constant or flat response characteristic and therefore, it can be used without corrections in response for this frequency range. Wide changes in damping-fluid characteristics have little effect on the calibration up to 1500 cycles, however, its action will be affected in responding to transient phenomena. (See Bibliography #3).

For frequencies greater than 1500 cycles corrections in response or calibration may be made by referring to the curve, Fig. 13. For any frequency between 1500 to 6000 cycles per second it is recommended that the calibration be checked with a thermocouple meter each time the vibrator is used, as a change in temperature at these frequencies has its greatest effect. At frequencies above 6000 cycles per second, wide changes of temperature again have little effect.

The watt dissipation of the element, as in most oscillograph vibrators, is so small that the ordinary continuous vibrator current has practically no effect on the damping fluid temperature and consequently can be neglected.

The standard vibrator, when measuring current values, is connected across a current shunt with a series resistance to control its deflection. As all the oscillograph shunts are designed to give ¼ volt output at their rated or engraved current, the standard vibrator requires a series resistance of 4 to 4½ ohms to give one inch overall alternating current deflection on the film or viewing screen. For the same deflection on a-c. voltage peak-to-peak, a series resistance is added of 19 ohms per volt or 2280 ohms per 120 volts r.m.s. On d-c. this value becomes 6¾ ohms per volt per inch deflection. For the maximum safe carrying current through the vibrator, 2¼ ohms per volt is required in series.

The fusing-current of the standard vibrator element is in the neighborhood of 1¼ to 1½ amperes.

Current above the continuous safe current rating will produce heating effects which will cause a blurred image and it may also anneal the element thus changing its calibration.

Sensitive, and Sensitive Fin Vibrator

The characteristics of the sensitive and the sensitive-fin vibrators are shown in Figs. 9, 15 and 29-A, curve B. The sensitive vibrator is constructed similar to the standard except that its element suspension strips, also its reflecting mirror are smaller. Its length of suspension between bridges is twice that of the standard. The undamped resonant frequency is but half that of the standard with six times the sensitivity, that is, it takes one sixth the current to deflect the light-beam a corresponding amount.

At a temperature of 20° to 23°C. the sensitive vibrator is adaptable to current, voltage, and instantaneous watt indications up to 1250 cycles per second at an accuracy in response of 2%. At 1750 cycles its response drops to 80%. The response of the sensitive vibrator is 22% at 4000 cycles which is comparable to the standard at 10,000 cycles per second.

The sensitive-fin is essentially a sensitive-vibrator plus a fin to overdampen it to give average instead of instantaneous deflections as given by the sensitive. It may be used to indicate average values of single-phase watts, rectified currents or voltages and for eliminating the ripple in constant current phenomena as for example, to eliminate the commutator ripple when interested in recording direct current output only of a d-c. generator.

When using either the sensitive or sensitive-fin for current or for voltage indications, it is connected into the circuit similar to the standard vibrator (see discussion under Standard Vibrator.)

When using these vibrators for wattage indications the vibrator elements are used as the voltage coils of the watt galvanometer and the stationary coil in the magnet well is the current coil. Of course, a swamping resistance must be used in series with the voltage or vibrator coil to limit the current to not more than the continuous safe current of 300 milliamperes as given in Table, Fig. 9.

The sensitivity of the watt galvanometer is the product of the direct current through the vibrator multiplied by that through the current coil, per inch of beam deflection on the film surface or viewing attachment.

The required resistance in series with the sensitive vibrator in the permanent magnet well to give a one inch deflection

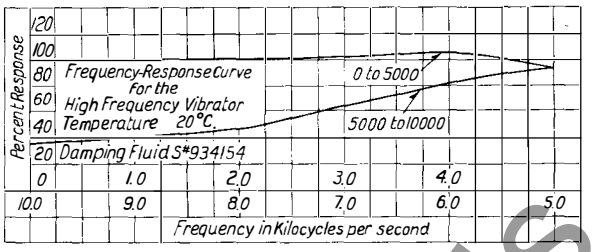


FIG. 12—FREQUENCY-RESPONSE CURVE FOR THE HIGH FREQUENCY VIBRATOR FOR A FREQUENCY RANGE OF FROM ZERO TO 10,000 CYCLES PER SECOND.

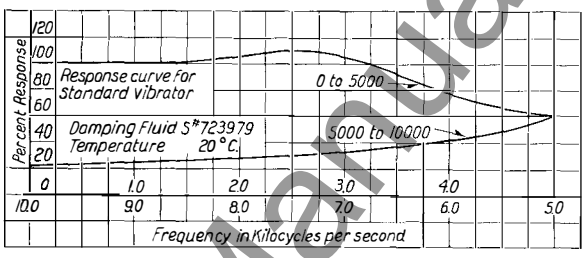


FIG. 13—FREQUENCY-RESPONSE CURVE FOR THE STANDARD VIBRATOR FOR A FREQUENCY RANGE OF FROM ZERO TO 10,000 CYCLES PER SECOND.

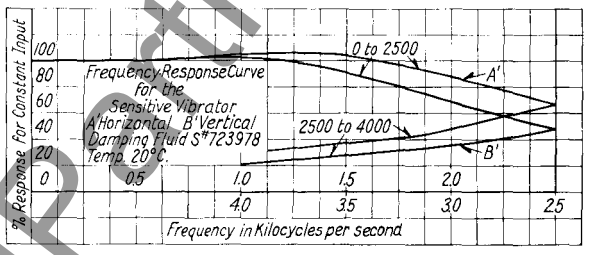


FIG. 14—FREQUENCY-RESPONSE CURVE FOR THE SENSITIVE VIBRATOR FOR A FREQUENCY RANGE OF FROM ZERO TO 4000 CYCLES PER SECOND.

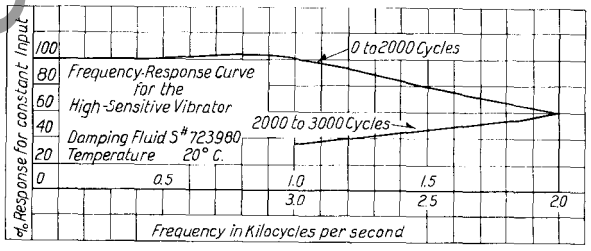


FIG. 15—FREQUENCY-RESPONSE CURVE FOR THE HIGH-SENSITIVE VIBRATOR FOR A FREQUENCY RANGE OF FROM ZERO TO 3000 CYCLES PER SECOND.

d-c. is 39 ohms per volt, to give one inch deflection overall a-c. is 110 ohms per volt, and to give the continuous safe carrying current is 3.5 ohms per volt.

The fusing current of the sensitive vibrator element is in the neighborhood of one ampere.

The single-phase instantaneous watt galvanometer most commonly uses the sensitive vibrator. In power transmission study a record by the single-phase watt can be made to reveal more perhaps than any other single reading Fig. 16 is an analysis of an instantaneous watt curve showing some of the indications obtainable from the amplitudes of the trace only. The fact that these indications are gotten from the amplitudes of the curve is important as the measurements are independent of film speeds. The indications obtainable from a single instantaneous watt record are: instantaneous power, average power, power-factor and phase angle, also the current providing the voltage is a constant which it usually is. (See Bibliography # 1).

High Sensitive, and Super-sensitive Fin Vibrators

Similarly, these vibrators are constructed like those described in the previous paragraphs except that their element suspension strips and their reflecting mirrors are still smaller. These vibrators are all interchangeable in the same permanent magnet well, as used by the standard or sensitive. The performance characteristics of these elements are shown along with the rest in Figs. 15 and 17. The sensitivity of the high sensitive is twenty-five and the supersensitive is seventy-five times that of the standard. The undamped resonant frequency of the high sensitive is a little more than one-half and the supersensitive is one-fourth that of the standard. The only difference in construction between the high and super elements is that the high has one-half inch bridge span and the super is one inch.

The supersensitive fin is essentially a supersensitive vibrator with the addition of a fin to over-dampen it to give average deflections and is used for the same purpose as the sensitive fin*, except that it is about twelve times as sensitive.

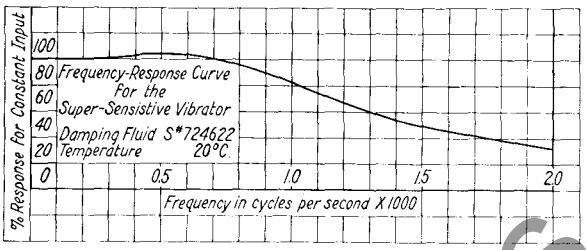
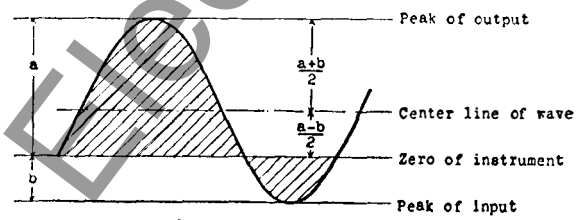


FIG. 17—FREQUENCY-RESPONSE CURVE FOR THE SUPER-SENSITIVE VIBRATOR FOR A FREQUENCY RANGE OF FROM ZERO TO 2000 CYCLES PER SECOND.

These three vibrators are obviously used where low operating energy is an essential feature, as examples: a voltage indicator with low energy amplifiers and often where amplifiers are omitted entirely. These elements also work very well as the voltage element in the single-phase watt galvanometer. The high-sensitive is more adaptable to the higher frequencies while either are particularly qualified to show ripple to an exaggerated degree in direct current quantities, as for instance, commutator ripple in generators. On the contrary the super-fin can be used to dampen out the ripple on large direct currents to give average deflections.

The safe continuous current for these elements is 130 milliamperes and their sensitivities are 6 and 2 milliamperes respectively for the high and the super-elements which means that extremely large deflection can be obtained. Inasmuch as these vibrators can be adjusted independently of the wells by means of an external thumb pinion, this feature becomes a very convenient and an extremely important item in numerous cases. All the galvanometers in this oscillograph have this distinguishing feature, that of being adjustable back to zero by an external adjustment. Any galvanometer beam can be adjusted back to a zero position up to a deflection of approximately twenty-two inches either side of zero. That is, the amount of adjustment back to zero on either side depends upon how the mirror is cemented on the element strips. If it cannot go the full twenty-two inches in one direction, it will go more than that amount in the other direction, the total being approximately the same. Moreover, if greater than twenty-two inch deflections are desired, then the mirror can be cemented slightly tilted to one side to favor the direction of deflection. Even though the vibrator frame can be adjusted throughout the ranges mentioned, the element may be made to go 30 inches or better by this method, provided the safe current carrying capacity of the element is not exceeded.

*See discussion under sensitive vibrator.



$$\frac{a+b}{2} = \text{volt amperes effective value}$$

$$\frac{a-b}{2} = \text{average watts}$$

$$\frac{a-b}{a+b} = \text{power-factor}$$

FIG. 16—DETERMINATION OF POWER FACTOR FROM INSTANTANEOUS WATT CURVE.

The maximum beam deflection that a galvanometer will give is calculated by dividing the safe continuous current by the galvanometer current-sensitivity, as given in Fig. 9 and tabulated in Fig. 18. In this particular case we get 20 inches for the high sensitive and 56 inches for the super-sensitive which indicates why these two vibrators find such a wide use in studying the ripples and irregular currents found in rectification, commutation and welding problems. Because of the mechanical limitation of the motion of the element, values beyond 22 inches cannot be utilized unless the mirror is tilted as explained previously.

The last column Fig. 18 shows maximum beam deflections for the galvanometers. Deflections greater than the five-inch film or ground glass width are measured by applying enough current at a time to bring the beam to the edge of the ground-glass. While the current is steady, the deflection is measured and the beam adjusted back to zero or the other extreme edge of the ground glass. This sectionalized measurement is carried on until the safe continuous current is reached or until the thumb-pinion has turned the vibrator to the extreme edge of its pinion-rack.

This adjustment gives two distinct and important advantages: first, the element strips are always kept in the field of maximum torque and hence, uniform sensitivity; and second, the reflected light beam from the element mirror always passes through the lens window at an efficient angle and therefore, the beam is always with a minimum of coloring or loss of light.

The required resistance in series with the high and super-sensitive elements to give one inch deflection d-c. is 1.54 ohms per volt and 435 ohms per volt respectively to give one inch deflection over all a-c. is 4.35 ohms per volt and 1230

Table of
BEAM DEFLECTION AND VIBRATOR BURDEN ⊕

Vibrator	Safe Continuous Current in Amps.	Direct Current Sensitivity in Amps.	Maximum Beam Deflection	Approximate Volt—Amp. Burden		∅✣ Series Ohms per Volt per Inch Deflection for D-C.	∅ Series Ohms per Volt for Max. Safe Current
				1″ D-C. Deflection	A-C. 1″ Peak to Peak		
Standard {Vertical / Horizontal	.450	.150	3 In.	.0180 .0135	.00225 .00169	6.67	2.22
Sensitive {Vertical / Horizontal	.300	.025 .030	12 In. 3.5 In.	.00094	.000117	40.0 33.3	3.33
High Sen. {Vertical / Horizontal	.130	.0065	20 In. 3.5 In.	.00023 .00017	.000029 .000021	154.0	7.7
Super-Sensitive Vertical	.130	.0023	56 In.	.00003	.0000036	435.0	7.7
Twin Vertical	.360	.0425	7 In.	.00270	.000338	23.5	3.33
Ultra-Sensitive Vertical	.006	.000075	30 *In.	.000112	.000014	13333.	166.
High Frequency {Vertical / Horizontal	.300	.285	1 In.	.180 .135	.0225 .0169	3.5	3.33

∅ Does not include element or field resistance.
✣ For one inch deflection peak-to-peak on A-C. multiply ohms for D-C. by 2.83.
* This value is limited by the construction of this type of galvanometer. See description under this title.
⊕ Where only one quantity appears in the space opposite each vibrator, it applies to both types, i.e. vertical and horizontal.

Fig. 18

ohms per volt respectively, and the maximum safe continuous effective current is 8 ohms per volt for either vibrator.

The fusing current for these three vibrators is approximately .45 amperes.

Twin Vibrator

Description

As the name indicates, the twin vibrator has two independent elements assembled on a single vibrator frame. The vibrator is mounted in a permanent magnet-well similar to the standard. The only difference between the twin and standard magnet-well is that the magnet air-gap is wider in the twin to allow for the additional element. This wider air-gap means that the twin magnet-well is used for the twin vibrator only and the twin-vibrator cannot be placed in the standard magnet-well without damage. The details of the twin are shown in Figs. 20 and 21 which are self-explanatory.

With reference to Figs. 20 and 21, the cam shaft of the twin vibrator extends from the top frame to a bearing support on the stem. Running at right angles to the stem is a curved shaped rocker-arm anchored on one end to the stem and on the other end is an adjustable screw which rests on the cam of the shaft near the stem support. In the middle of this rocker-arm is a tongue-projection on which is an ivory auxiliary bridge. This auxiliary bridge rests against the inside ribbon of each element. Then, by turning the cam-shaft the cam raises and lowers the auxiliary bridge mechanically through the rocker-arm. Raising and lowering of this bridge tilts the mirrors away and toward each other as a result of one ribbon of each element resting on this actuated bridge. Therefore, the light beams which are reflected from these twin mirrors will spread or come together as this cam shaft is turned. There is a screwdriver slot in the top end of the cam shaft, hence, with a small screwdriver the beams can readily be adjusted with respect to each other. Both spots can be moved across the screen without upsetting their spacing, by the usual adjustment knob common with all the galvanometers.

Table of
WATT GALVANOMETER BURDENS

Watt Galvanometer	Field Coil Volt-Amp. Burden @ 5 Amperes		Element Burden Per In. Def. @ 5 Amp. in Field Coil and Unity P.F.	
	60 C.	25 C.	Inst.	Avg.
Single Phase	1.7 VA	.87 VA	.00487 VA‡	.01950 VA
Polyphase Inst.	1.6 VA	.76 VA	.0210 VA*	.....
Polyphase Avg. Value	.5 VA	.31 VA	.....	.00146 VA*

‡ Peak-to-peak measurement.
* Per coil for 1″ deflection on balanced 3 phase power.

Fig. 19

Application

The twin vibrator is used for measuring current and voltage with an accuracy and over a frequency range similar to the sensitive vibrator described previously as may be seen from the curve Fig. 22. At frequencies above 200 cycles per second the adjacent element commences to pick up the frequency from the other element due to the mechanical-coupling of the damping fluid. This coupling effect increases to a maximum of 17% of the deflection on the adjacent element at about 1500 cycles. This coupling can be used to an advantage by placing the high frequency being measured and the timing current on adjacent elements in a twin galvanometer. As for example, the timing current of the order of 100 cycles per second on one element of the twin and an investigated or unknown frequency in the order of 1000 cycles on the other element of the wire, then the oscillogram will show the timing wave with the unknown high frequency super-imposed on it. This very conveniently helps in counting the unknown or if the high frequency is known, it can act as a fine division scale in timing other phenomena. It must be definitely understood that this interference occurs only with the twin elements in a single magnet-well, there is positively no interference between adjacent galvanometers. In no case are any of the vibrators inductive

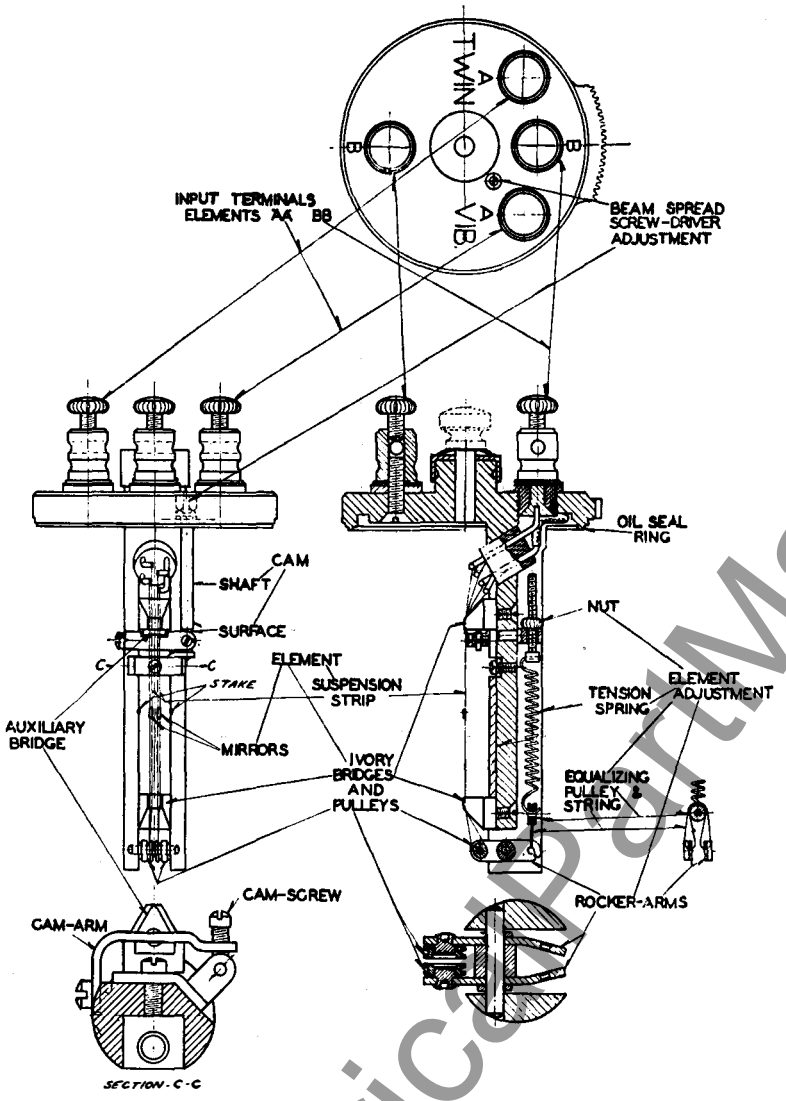


FIG. 20—DETAIL ILLUSTRATED VIEWS OF THE TWIN-VIBRATOR.

to the extent that any frequency will induce an inductive interference that will be seen let alone measureable on this type of vibrator.

Caution should always be used to keep the two elements in one well near the same potential, as at near a 100 volts, the potential difference between elements in the same air-gap as each commences to show an electrostatic pick-up from the adjacent element. (See Fig. 22-B). Careful connections can always avoid high potentials between elements in one well. For instance, in measuring a current and a voltage of a single-phase source, connect the voltage element next to the current element and put all the swamping resistance from that point to the high potential side of the line.

The required resistance in series with the twin element to give one inch deflection dc. is 23.5 ohms per volt and 66 ohms per volt to give one inch deflection overall ac. To give the safe carrying current it requires 3.5 ohms per volt both ac. or dc.

The fusing current of the twin vibrator element is in the neighborhood of one ampere.

Galvanometer Fuses

The vibrator fuses have been selected to give complete protection to the elements even if they are operated in air. With the proper fuse, the element will be protected even if accidentally placed across the 120 volt supply whether ac. or dc.

In using fuses, it should be kept in mind that they have resistance and that this must be considered when figuring the total resistance to control the element deflection. In addition, the fuse resistance is affected by temperature, especially when the current value approaches the blowing point of the fuse. When the fuse resistance approaches the total resistance controlling the deflection, this change in resistance effect will be most noticeable. This is particularly true when measuring currents with the element directly or when used with the shunts in which cases it is often necessary to eliminate the use of the fuse altogether. Curve and table in Fig. 22-A gives the fuse characteristics.

Single Phase Watt Galvanometer

Description

The single-phase watt galvanometer is shown partially assembled in Fig. 23. The metal die-cast well is common with all watt galvanometers and mounts in the same bracket and has the same space requirements as the permanent magnet well.

To the top plate is assembled the electro-magnet field with a 5 ampere current coil. This current coil is tapped at ⅙ of its turns for momentary records of 30 amperes. The ohmic resistance of the full field coil is .026 ohms.

The voltage element of this galvanometer is placed in the air gap of the electro-magnetic field and may be any of the elements that operate in the regular permanent-magnet well. The sensitive or sensitive-fin previously described are the elements most commonly used. When the sensitive-fin is used, the galvanometer is known as the "Single-Phase Average Watt Galvanometer". The sensitivity is shown in

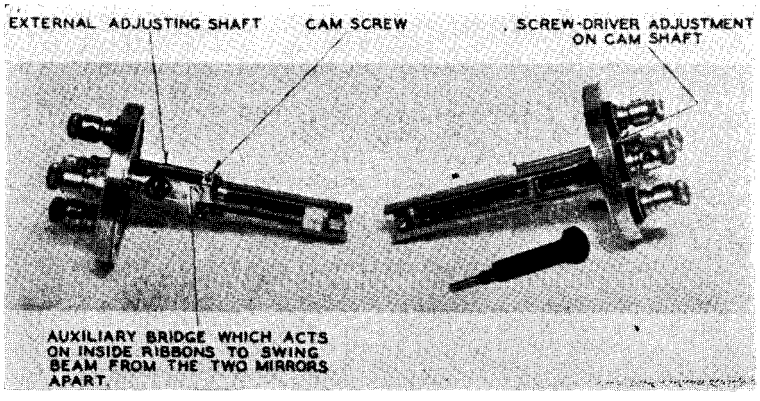


FIG. 21—FRONT AND BACK VIEW OF THE TWIN-VIBRATOR REMOVED FROM THE MAGNET-WELL.

Fig. 9, and the response characteristics of the voltage element in Fig. 14.

Application

This galvanometer was designed to measure single-phase instantaneous watts, average watts, power-factor, phase-angle, and current provided the voltage is constant.

The current-winding or full-field coil is intended for use in the 5 ampere secondary of any instrument transformer and will operate with 5 amperes continuously or 1000% overload for a duration of one minute.

The potential or voltage element may be used to measure voltage direct through suitable resistance as described for the sensitive vibrator.

Standard control panels may also be used to supply the potential. See Description under "Control Panels". This also applies when the galvanometer is used to measure phase angle direct when the current and voltage winding are connected to the "Angle Control Panel".

Corresponding polarity connections to the coil in the well and the vibrator will give a deflection to the right facing the galvanometer. The insulated terminal of the vibrator is the ± terminal.

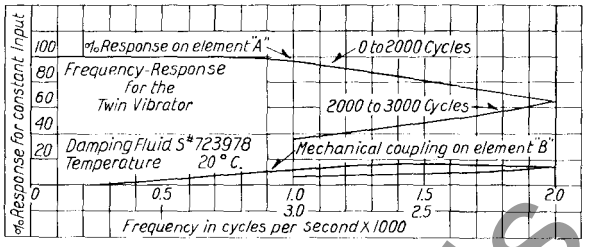


FIG. 22—FREQUENCY-RESPONSE AND MECHANICAL-COUPLING CURVES FOR THE TWIN-VIBRATOR FOR A FREQUENCY RANGE FROM ZERO TO 3000 CYCLES PER SECOND.

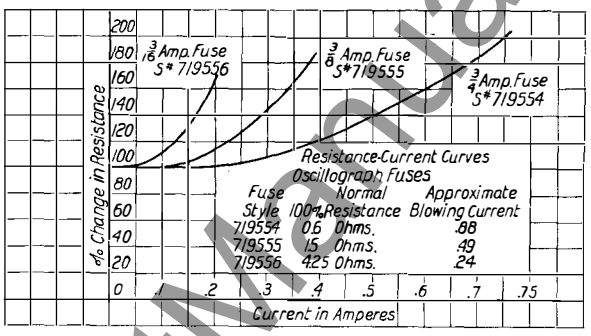
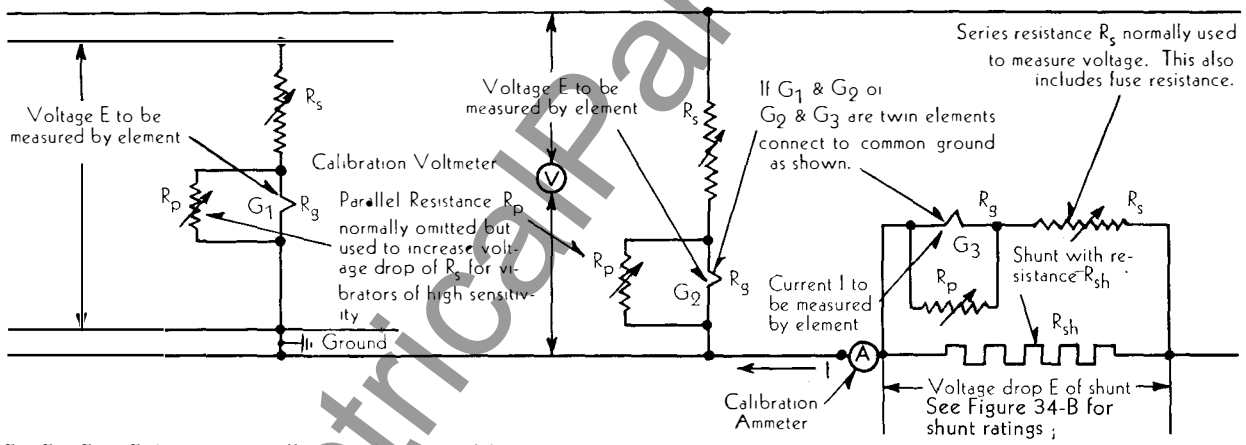


FIG. 22-A—THE ABOVE CURVE AND TABLE SHOWS THE RESISTANCE CHARACTERISTICS OF THE OSCILLOGRAPH FUSES.



G_1, G_2, G_3 = Galvanometer vibrator elements with resistance R_g and sensitivity S_{dc}.
S_{dc} = Sensitivity in amperes per inch deflection D.C. see Figure 9
V = Calibration Voltmeter—Optional for voltage measurements
A = Calibration Ammeter—always used with shunts
I_g = Current flowing in the galvanometer vibrator G_1, G_2, G_3 = Deflection in inches x S_{dc}.

$$= \frac{E}{R_s\left\{1+\frac{R_g}{R_p}\right\}+R_g} \quad \text{or} \quad = \frac{E}{R_s+R_g} \quad \text{when } R_p = \infty \text{ (i.e. omitted)} \ldots\ldots (1).$$

D.C. deflection of G_1, G_2, G_3 = $\frac{I_g}{S_{dc}} = \frac{E}{S_{dc}\left[R_s\left\{1+\frac{R_g}{R_p}\right\}+R_g\right]}$ or $= \frac{E}{S_{dc}(R_s+R_g)}$ when $R_p = \infty$ ..... (2).
(for safe values see Figure 17)

A.C. deflection = D.C. deflection x 2.83 for I_g r.m.s. A.C. ..... (3).

Voltage E per inch deflection of G_1, G_2 from circuit constants $= S_{dc}\left[R_s\left\{1+\frac{R_g}{R_p}\right\}+R_g\right]$ or $= S_{dc}\left\{R_s+R_g\right\}$ when $R_p = \infty$ .. (4).

Current I per inch deflection of G_3 from circuit constants $= S_{dc}\left[1+\left(R_s\left\{1+\frac{R_g}{R_p}\right\}+R_g\right)\frac{1}{R_{sh}}\right]$ or $= S_{dc}\left[1+\left\{\frac{R_s+R_g}{R_{sh}}\right\}\right]$ when $R_p = \infty$ .. (5).

FIG. 22-B—GALVANOMETER CONNECTIONS FOR MEASUREMENT OF CURRENT OR VOLTAGE WITH STANDARD, SENSITIVE, SUPER-SENSITIVE, HIGH-SENSITIVE OR TWIN ELEMENTS.

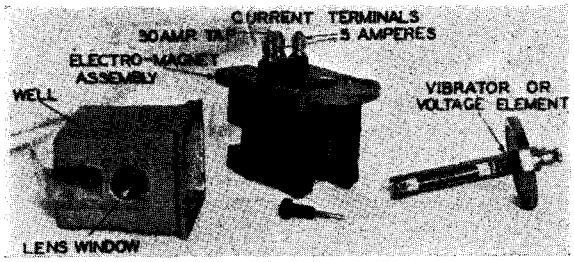


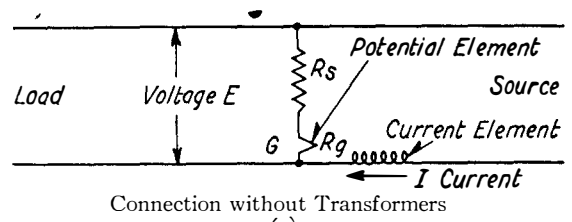
FIG. 23—THE CURRENT UNIT OR THE ELECTRO-MAGNET ASSEMBLY OF THE SINGLE-PHASE WATT GALVANOMETER REMOVED FROM THE DIE-CAST WELL WITH THE SENSITIVE VIBRATOR TO THE RIGHT.

Calibration

In order that this galvanometer indicate actual power in watts, it must be calibrated by using a single-phase wattmeter. Otherwise the sensitivity in current squared per inch (A^2) should be used, which is normally taken as the product of the field current and the voltage element current when dc. is used, in both the voltage and current winding, see Fig. 23-A.

Operation

To measure single-phase power, the galvanometer can be connected as shown in Fig. 23-A or as shown for the half-length potential panel Fig. 48. When used to measure phase angle, the "Angle Control Panel", Fig. 50 is used, (also see description under this heading).



Connection without Transformers (a)

Connections with Transformers (b)

Calibration should be made with a wattmeter wherever possible, otherwise, the sensitivity of the galvanometer should be determined accurately and this value may be used to calculate the voltamperes per inch of deflection as follows:

G = Sensitive vibrator element with sensitivity Sdc (See Fig. 9).
I_f = Current in coil of watt well (see description under heading for safe current capacity).
I_g = Current in potential element which should not exceed safe value (see Figs. 22-B and 18).
Sw = Sensitivity of watt galvanometer in amperes squared per inch. (see Fig. 9).

D-C. deflection in inches $= \frac{I_g \times I_f}{S_w}$ ..... (1)

A-C. peak-to-peak deflection in inches $= \frac{2\, I_g \times I_f}{S_w}$ ..... (2)

$= \frac{2\, E \times I_f}{S_w (R_s + R_g)}$ where $I_g = E/(R_s + R_g)$ (see Fig. 22-B equation 1) ..... (3)

Voltamperes r.m.s. per inch deflection peak-to-peak $= \frac{S_w}{2} (R_s + R_g) = \frac{(a + b)}{2}$ from Fig. 16 ..... (4)

For Power Factor relations see Fig. 16.
When using potential transformers as in (b) E and It should be corrected for the ratio of transformation.

FIG. 23-A—SINGLE-PHASE WATT GALVANOMETER CONNECTIONS AND METHODS OF CALIBRATION. ALSO SEE FIG. 16.

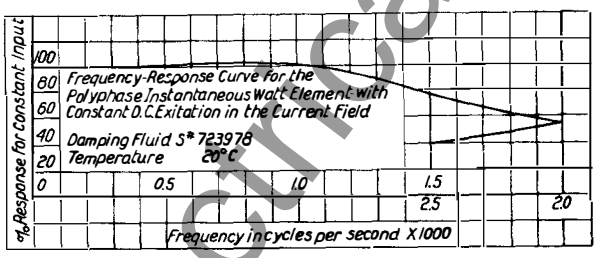


FIG. 24—FREQUENCY-RESPONSE CURVE FOR THE POLYPHASE INSTANTANEOUS WATT VIBRATOR FOR A FREQUENCY RANGE OF FROM ZERO TO 2500 CYCLES PER SECOND, TAKEN BY HOLDING A CONSTANT D.C. EXCITATION IN THE CURRENT FIELD.

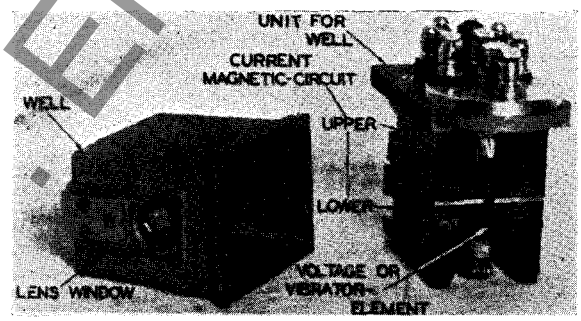


FIG. 25—THE POLYPHASE INSTANTANEOUS WATT GALVANOMETER AS IT APPEARS REMOVED FROM THE WELL.

The indications of the single phase watt galvanometer in power transmission studies can be made to reveal more perhaps than any single reading. Fig. 16 shows an analysis of the instantaneous watt curve and gives some of the indications obtainable from the amplitude of the trace only. The fact that these indications are gotten from the amplitudes of the curve is important, as the measurements are independent of film speeds.

The Polyphase Instantaneous Watt Galvanometer

Description

This galvanometer, Fig. 25, has two electro-magnets assembled in one well and these are excited by the line currents. A double vibrator element operating in the field of these electro-magnets is excited by the line voltages. The current coils can be used directly in the line or from current transformer secondaries and will carry 5 amperes continuously and up to 15 amperes before

saturation of the core begins. However, a means must be provided to limit the current through the potential or vibrator elements, as the resistance of each element is but 0.7 of an ohm and the safe continuous current is but 300 milliamperes which is the maximum permissible burden of but .063 watt. These potential currents are usually controlled by the half or full length potential control panels.

In the arrangement of input terminals, the "double vibrator" resembles the "twin", but the suspension resembles the "sensitive" in that it has two separate strips. The end of each is soldered to the usual terminal studs at the top and the other end of each strip is soldered to a rocker-arm at the extreme end of the frame. The middles of these parallel strips are soldered together back of the element mirror. One of the single-loop potential-elements is from one upper terminal post down the strip through the soldered joint back of the mirror and up the strip to the other upper post, and the other single-loop potential element is from one rocker-arm up the strip, through the soldered joint behind the mirror and down the strip to the other rocker-arm. The two upper terminal posts and the two rocker-arms are each electrically connected to a pair of input terminals. The terminals for the upper coil are designated U ± and U and the lower by L ± and L. Similarly the well carries a corresponding notation.

Corresponding polarity connections on the upper coils of both the well and vibrator or similarly on the lower coils, will give a deflection to the right facing the galvanometer.

Application

The "double vibrator" gives practically a flat response to above 1000 cycles (see Fig. 24) and with the two-coil well, it gives true instantaneous power on one, two or three phase systems for all frequencies up to and including 1000 cycles. On a three-phase system, the hook-up is the conventional two-wattmeter connection for a system of three wires. For measuring power on more than one phase, careful balancing must be made, as described in the following paragraph.

Calibration

Before using the element to record polyphase power, it should first be balanced on a singe-phase circuit. To balance with the use of either the half or full length potential panels, connect the primaries of the two potential transformers supplying the potentials to the elements in parallel and hence, across a single-phase 120 volt circuit. Connect the current coils of the well in series **opposition** in the same single-phase circuit. Energize the galvanometer with 5 amperes and the transformers with 120 volts, preferably on a unity power factor load. Then by arbitrarily setting any value of resistance in one secondary potential circuit, select a peak-to-peak deflection approximately equal to the indication desired for the polyphase measurements. Now adjust the resistance in the other secondary potential circuit until the reflected beam shows no deflection and no ripple. When this is done, the galvanometer is ready for polyphase indication. When using it in a balanced polyphase circuit under identical power factor conditions as used for calibration, the resultant deflection will be approximately 86% of the peak-to-peak deflection determined by the previous setting. However, if this deflection is still unsatisfactory any new adjustment will require a complete rebalancing. After a satisfactory condition has been established the rheostats should not be changed.

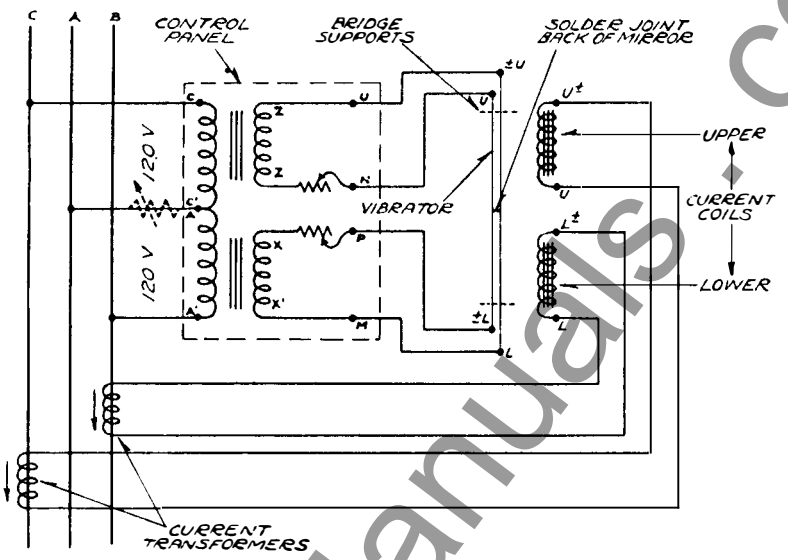


FIG. 26—SCHEMATIC WIRING DIAGRAM OF THE PROPER POLARITY IN CONNECTING THE POLYPHASE INSTANTANEOUS WATT GALVANOMETER ON A THREE-PHASE UNGROUNDED SYSTEM.

Operation

The primaries of the potential transformers should be connected in open delta or vee, and the connections to the current coils should be the same as for any ordinary wattmeter. The diagram of connections and vector relations are then as shown in Figs. 26 and 27.

The galvanometer may obtain its potential supply from terminal posts Q-Y′ and P-M or U-N and P-M or Q-Y′ and U-N of the full length potential panel. See wiring diagram, Fig. 26.

The vector diagram, Fig. 27, corresponds to the polyphase watt circuit connection, Fig. 26, or its common two watt meter connection. Corresponding polarity connections on both vibrator and field should give deflection to the right. To reverse the deflection of the galvanometer beam, reverse the polarities of both the voltage, coils or both the current coils. Refer to the wiring diagram and the vector diagram, and note that to measure watts **either** one potential or one current must be reversed.

If the line currents and voltages are perfectly balanced, the element should produce a straight line. If a ripple appears it may be due to any of the following reasons:

1. The polarities of some of the currents or voltages in the element may be reversed. This can be checked by reversing the several leads in turn.

2. The potential elements may be connected to react with the wrong current coil. This may be checked by interchanging the potential leads.

3. There is always some ripple caused by interference of the upper current coil with the lower potential coil and vice versa. It cannot be eliminated within the element because of the impossibility of making a perfect magnetic shield, and varies between different galvanometers because of manufacturing variations. The amount of ripple which may be expected is shown in the oscillogram, Fig. 28. This was taken exciting the upper current coil and the lower potential element. A similar ripple, with 60 degrees phase difference, is produced by the lower current coil and the upper potential element. The sum of these two ripples will be the total interference ripple.

This ripple produced by this interference can be sufficiently suppressed by placing a rheostat in the common primary lead of the potential transformers which goes to the point of the Vee. The rheostat, indicated by the dotted lines, Fig. 26, may be adjusted until the ripple disappears or is a minimum. This rheostat will also take care of small unbalances in line voltage and small unbalances in the element which may not have been eliminated in the single phase balancing as previously described.

4. The wave forms of the voltages and currents may be non-sinusoidal. That is, there may be harmonics present. The ripple produced by these harmonics cannot be eliminated.

Tests have shown that the ripples produced by interference and unbalance can be easily reduced so as to be negligible by the methods outlined above.

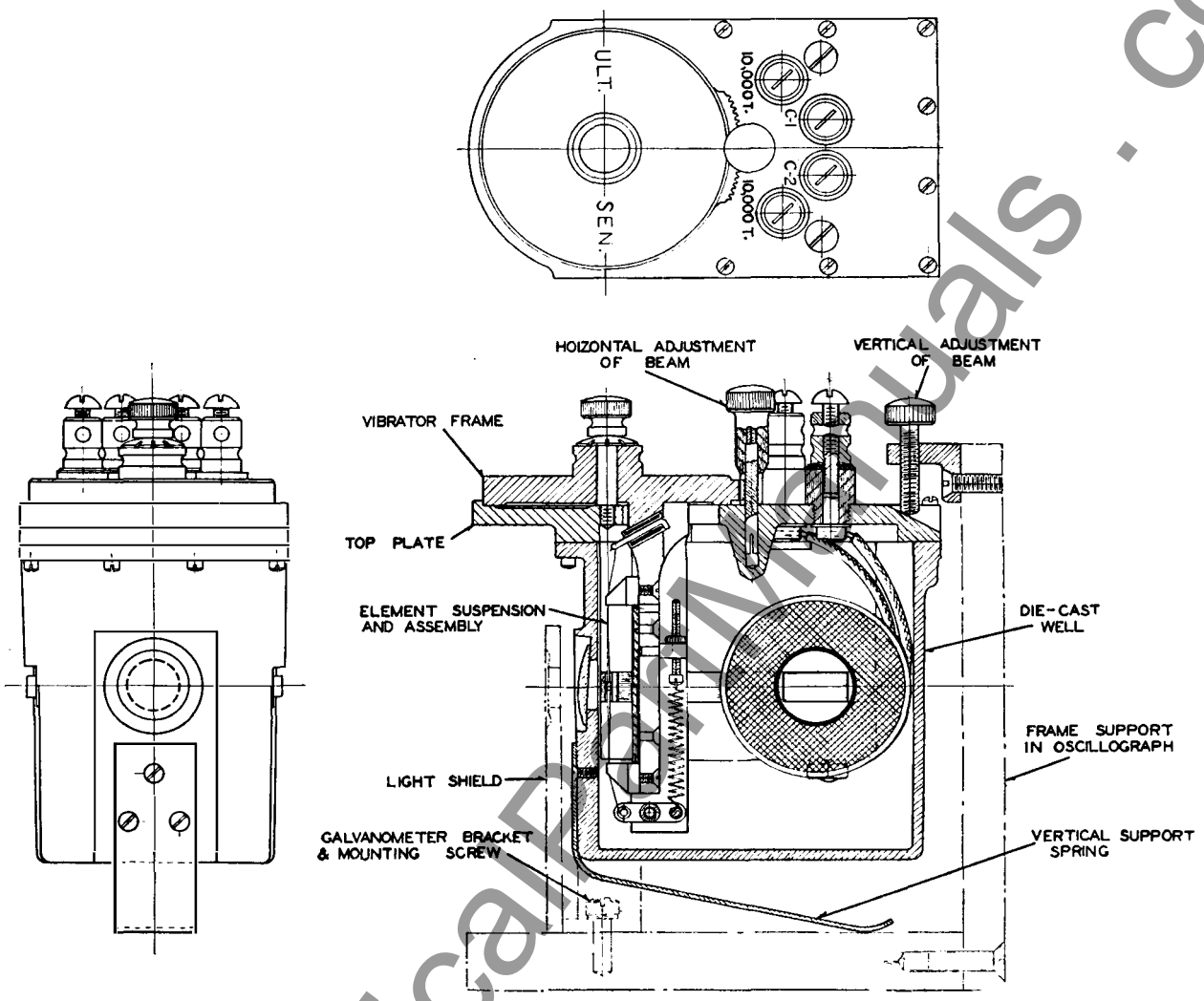


FIG. 31—TOP AND FRONT OUTLINE VIEWS AND A SIDE CROSS-SECTIONAL VIEW OF THE ULTRA-SENSITIVE GALVANOMETER COMPLETE MOUNTED IN THE OSCILLOGRAPH, SHOWING DETAILS.

vibrator-element and is assembled on the regular frame. The ribbon merely acts as a suspension and carries no current. This little permanent magnet hangs with its pole center line at right angles to the electro-magnetic field, and on the ends of the poles is the regular element mirror. The slightest field, set up by the electro-magnet, actuates the permanent-magnet and deflects light beam by tilting of the mirror attached to the small magnets.

Application

The characteristics of this galvanometer are shown in Fig. 9 and Fig. 31-A. The field resistance is 20,000 ohms with an inductance of approximately 45 henries. Although the free period in air is 700 cycles, the inductance does not permit as wide a frequency range as is possible in other types. The maximum continuous field current is .006 amperes. The d-c. sensitivity is 75 x 10^{-6} amperes per inch deflection. Direct current components greater than 2.5 times the current required to deflect one inch or 25 x 75 x 10^{-6} amperes should not be used as the element becomes unstable, and the small magnet is likely to become demagnetized.

Due to the low field strength required to operate this element, it is sensitive to stray fields and should be used with care. For this reason they should not be used in adjacent compartments as the excitation of a field in one may cause motion of the vibrator in the other. It is recommended that not more than two of these be used to an oscillograph and that they be installed in the extreme positions. For these reasons the same precautions should be taken when using the ultra-sensitive near watt-galvanometers.

The ultra-sensitive finds its greatest use in measuring low frequency phenomena as found in geophysical and physiological studies. It is not adaptable to high frequency studies because of its low period and high inductive field. The high resistance field permits it to be used directly in amplifier circuits and as the field winding coils are separated, they may be center tapped for use in push-pull (amplifier) circuits. These field characteristics also permit it to be used to explore stray fields of motors, generators, and instruments. Exploring coils of a few turns will often give sufficient energy to produce the desired beam deflection.

Damping Fluids and Damping

No hard and fast rule can be made as to the fluid for properly damping out undue oscillations of the vibrating system. All fluids change their viscosity with temperature, and no one viscosity is perfect for all oscillograph work. Certain fluids have very desirable features, but, unfortunately, they have undesir-

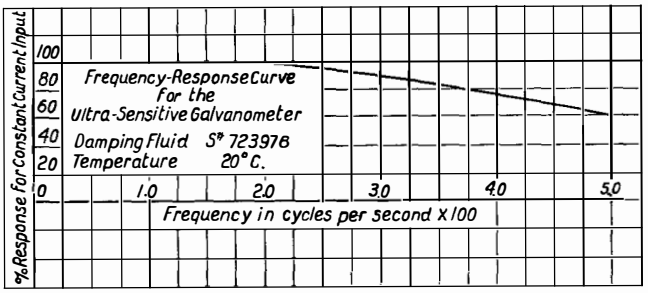


FIG. 31-A—FREQUENCY-RESPONSE CURVE FOR THE ULTRA-SENSITIVE GALVANOMETER WITH CONSTANT CURRENT INPUT AND FOR A FREQUENCY RANGE OF FROM ZERO TO 500 CYCLES PER SECOND.

able features as well. The fluid should be clear and transparent and should have no harmful effect on the mirror cement, window cement, or frame finish.

Fluids recommended for use (see Fig. 9) are satisfactory. These are mineral oils of U.S.P. standard and are water-white in color.

Any of these fluids may be mixed in any desired proportions. The mixing should always be done in a transparent vessel and the oil should not be added to the galvanometer until perfectly clear. Oils in the wells of the galvanometer may be added and removed by means of an ear syringe.

Oils such as vegetable and animal types are not recommended, as they discolor and gum with age.

Highly volatile solvents used sometimes to thin the oil should be avoided, as the oil's viscosity will continue to change due to evaporation.

For notes on damping, see Bibliography numbers 3, 5, and 6.

GALVANOMETER MAINTENANCE

Vibrator Removal

To remove vertical vibrators from the magnet-well, Figs. 8, 32 and 33, first unscrew and remove the center mounting screw with its spring washer. Next remove the black-insulated adjustment pinion, then take the vibrator by the terminal post, slightly lift it, at the same time slide it back toward the rear of the magnet-well about one-quarter inch, then withdraw vertically. While withdrawing the vibrator, make sure **not** to strike delicate element parts on the sides of the opening in the magnet-well. Reassemble in reverse order. These operations are shown in Fig. 33.

To remove horizontal vibrators Fig. 10 first remove the adjustable mirror assembly and pinion. Then remove the four recessed screws holding the top plate to the well. Break the well to top plate seal by inserting a screw driver in the small slots adjacent to the dowel pins. In order not to spring the pins each side should be raised alternately a little at a time. A sharp knife inserted around the joint will help this operation. A little care will preserve the joint gasket so it may be reused.

Vibrator and Well Oil Sealing

Before replacing a vibrator in the magnet-well, all traces of oil must be removed from the adjacent surfaces of the vibrator and well top-plate, by wiping with a cloth moistened with c.p. carbon tetrachloride. The vibrator should be immersed in this solution, and before reassembly the vibrator mirror should be cleaned with c.p. ether, by scraping the mirror surface with a small drop on the edge of a razor blade or an orange stick.

The two wiping surfaces of the vertical vibrator and top-plate, including the top surface of the gasket in the well top-plate, should be coated with a thin film of damp, strong alkali soap, such as "Fels Naphtha". In addition, the cap on which the spring washer of the center screw rests must be filled with sufficient quantity of the damp soap to just permit it to ooze out under the spring washer when the vibrator screw is fastened securely in the well. The screw should be inserted through the hole after the cap is placed back to make sure no soap will be caught on the thread to enter the well. **Under no circumstances must soap be permitted to enter the well.** After assembly of the vibrator and well, and the tightening of the center screw, the vibrator should be rotated back and forth several times to make sure that it has seated properly and that the center screw will not become loose from its seat under such motion. This type of oil seal has proved exceptionally effective at temperatures up to 40° Centigrade. However, it is not recommended to exceed this value.

All wells have gaskets between the well and top plate. In the vertical type this gasket separates the well and the top plate mounting the magnet. In the horizontal type two gaskets are used one of the well joint of the top plate, the other between the vibrator bridge mounting and the top plate. These gaskets are all sealed by means of shellac or cement S # 439228 (oil removed from wells and surfaces to be joined) and dried with heat not over 100°C. until the cement is hard. In the horizontal type the oil filling screw and oil overflow

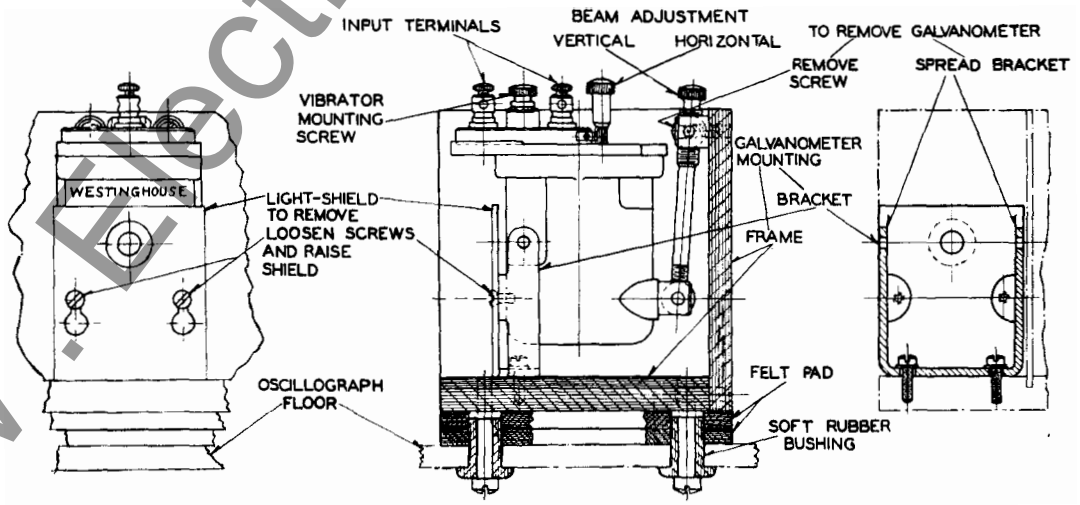


FIG. 32—THREE CUT-AWAY VIEWS OF THE COMPLETE GALVANOMETER SHOWING DETAILS OF THE MOUNTINGS.

cap should be removed and air should be blown through the assembly to keep the vibrator structure cool. If this is not done the vibrator mirror may become uncemented or distorted in position. This unit should be kept horizontal during this procedure.

In performing the above operations care must be taken that no oil whatsoever gets on the lens window. The lens may be cleaned with c.p. ether, using a soft clean cloth. Its appearance **must be crystal clear.**

Wells—Removal and Adjustment

Fig. 32 shows the vertical galvanometer assembly complete: To remove the galvanometer take off the light shield by loosening the screws as shown in the figure. Remove the screw and one of the upper support posts of the vertical adjustment as indicated and spread the support brackets by inserting a small screw-driver first between one leg of the bracket and the well side-wall, and then the other, and this permits the galvanometer to be taken out. This process is reversed for reassembly.

Care should be taken to be sure that all play between galvanometer and bracket is reduced to a minimum. The bracket holes may be swedged to produce a tight bearing fit and the spring tension of the bracket should be sufficiently tight so that any normal motion of the galvanometer in service or adjustment will always permit the beam to return to its normal zero position. If this is not the case the play may be in the vertical adjustment screw supports or nuts. Should wear permit this condition to exist, swedging of the nuts will produce sufficient friction to eliminate that trouble.

The horizontal galvanometers are mounted as a group of three on a subbase Fig. 2. To remove the galvanometers the four screws holding the subbase are taken out and the two screws holding each galvanometer to this base are removed from the bottom.

Reassembly is made in the reverse order. Care should be taken to note that all play in the adjustable mirror assembly is a minimum and that the mirror is clean and in perfect condition.

On removing either the vertical or horizontal galvanometers care should be taken to note that on reassembly the mirrors of the vibrator elements line up so as to focus in one plane on the photographic surface (see notes under galvanometer operation page 8 and notes on cementing of mirrors page 22).

When damping fluid is changed in the well, it should be replaced immediately with a similar kind to prevent the formation of a scum or film on the inside of the lens-window. Should a special kind of damping fluid such as castor oil be put into the well normally filled with the standard transparent white oils, a complete cleaning of the well and inside lens surface is required. This is accomplished as follows; Remove the screws holding the top-plate with its magnet structure to the well and break the shellac seal by inserting a knife where the top-plate joins the well, Figs. 8, 10 for the permanent magnet unit, and Fig. 23 for the watt units. Wash the magnet assembly and well assembly with c.p. carbon tetrachloride and allow to dry. **Care must be taken that no iron filings or dirt be allowed to find their way into the magnet air gap.** If this is the case, they may be removed by passing the gap through a high temperature blast or Bunsen flame for a fraction of a second. The magnet must not be permitted to become any hotter than 100°C. or better still, any hotter than can be safely handled by the hand. If no flame is available, the gap may be wiped clean with a damp cloth or brushed out with a stiff tooth brush.

The lens should be cleaned inside and out with c.p. ether, using a soft cloth. The final appearance of the lens must be crystal clear. Should the lens have to be removed, replaced or recemented, proceed as follows. Warm the well in an oven (not over 100° C.) until the cement under the lens becomes soft and the lens may be easily removed. To reassemble a lens it must be crystal clear and the well should be warm as explained, be sure the curved side is outside. Place a small quantity of shellac preferably cement S #439228 on the lens mounting surface, and put the lens in position taking care that the cement does not spread over the inside lens surface.

The well may be reassembled to the magnet structure and top-plate by the same process. When the assembly becomes cool, the cement will form a positive oil-proof seal.

Should the magnet structure become misaligned, it should preferably be returned complete to the factory for adjustment. However, the magnet may be aligned with a perfect vibrator, when the assembly has been removed by making equal clearance on either side of the ribbon in the air gap. If the magnet has become demagnetized, the complete unit should be returned to the factory for repair.

Restringing of Standard Sensitive, Twin, Super and High Sensitive Elements

These operations that follow apply equally well to all vibrators of the Duddell type, whether of the twin or single element type. Figs. 8, 10 show the springs which give the proper tension to the vibrator ribbons. In restringing the vibrator element, the tools required are: a small soldering copper, a noncorrosive soldering flux, solder, heavy paper, such as is used in a card-index, a toothpick, a small bottle of alcohol, magnifying glass, lens paper, and a sharp penknife or safety razor blade.

The extremely fine ribbon should be handled as little as possible for any small kink or bend in the ribbon will impair the characteristics of the finished vibrator. The finished length of the standard vibrator ribbon is about 3½ inches. Approximately 5 inches of ribbon are required to properly restring the vibrator element.

With a suitable ribbon length, allow one end of it to be weighted by using one of the mirror bottles as one free end of the wire can be wedged between the cork and the glass. The other free end is to be soldered and the weight will prevent the ribbon from becoming tangled while this operation is performed.

Heat the soldering copper and clamp the vibrator horizontally with the pulley end towards you. Then remove the remains of the silver strips from the tinned terminals, located above the ivory bridges and below the element frame top. Then carefully wedge the toothpick, or sliver of wood so as to hold the lever in such a position that the ivory pulley is at right angles to the element frame. Make a small loop in the vibrator ribbon at the unweighted end and after touching it with the flux, slip this loop over the end of the ribbon underneath, and slightly to the left of the center so it will "line up" with the left hand slots in the ivory bridges in which position the weighted end may be made to hold the ribbon under the pulley and in the bridge slots. Then touch it with the end of the soldering copper with enough solder to hold it in place. (If the copper is too hot, it will anneal the ribbon.) Draw the ribbon over the ivory bridges so that it will lie flat in the left-hand slots, then draw it around the tiny ivory pulley back over the ivory bridges, making it lie flat in the right-hand slots by completing a half turn about the upper tinned terminal. All slack should be drawn out of the ribbon after the ribbon is made to lie flat in all four slots. When the ribbon lies flat in the slots and between the bridges, touch the upper tinned terminal with the flux and solder the ribbon in place (slightly to the right of the center and in line with the respective slots). The loose ends of the ribbon may be cut off with a razor blade. Remove the tension from the ribbon by a slight finger pressure on the under side of the ivory pulley, then remove the wedge from the lever and allow the ivory pulley to be drawn down by the force of the spring until the ribbon is under tension. If the lever remains approximately horizontal then the tension is sufficiently correct provided the initial adjustment has not been changed.

The tension of the ribbon may be measured by hanging a known weight from a small wire hook placed over the pulley arm in line with the spring when the vibrator is vertical. When the ribbon just begins to show slack, the weight equals the spring tension. The tensions are 6 ounces on the standard, 4 ounces on the sensitive, and 4 ounces on each element of the twin or 8 ounces total on the spring. On the high and super-sensitive the tension is ⅓ ounce.

Restringing of High-Frequency Element

The process previously described for the standard elements, etc., apply here except that in this case a different ribbon alloy is used which has the ends to be soldered copper plated. Care should be taken to note that the copper plated ends are of sufficient quality to permit a good soldered joint. The normal tension is 6 ounces although higher tensions up to 9 ounces may be safely used on this element.

Restringing of Polyphase Instantaneous or Double Vibrator

In this case the vibrator ribbon is handled the same as the sensitive except (see description of this vibrator under that heading) at the point where the wire would normally go over the pulley there is a double arm arrangement to which the left and right hand ribbons are soldered each to their corresponding arm or lever. Both these levers must be 90 degrees to the element frame as prescribed for the pulley. At the center of the bridge span on the back of these two parallel ribbons is now soldered a small piece of ribbon which must join both ribbons together at the middle. The tension is 4 ounces.

Restringing Polyphase Average Value or Three Coil Vibrator

This vibrator has a construction which permits the suspension to be repaired if broken but not the coils. If the coils are defective, the element must be returned to the factory. The broken suspension wire may be removed from its shield of aluminum tubing on which the 3 coils are mounted by loosening the small screw directly behind the center of the middle coil. Care should be taken not to strip the threads of the screw or break the coil connections. In case it is desired to disconnect the coils for this operation, the coil ends and points of contact should be marked as the polarities are very important.

Soldering operations are carried out as previously described except that in this case the lower terminal at the foot of the vibrator is the only soldered connection. The upper terminal clamps the wire which should be pulled through the center hole of the vibrator so that a tension of 2 ounces can be applied before clamping the suspension.

Restringing of Ultra-Sensitive Vibrator

As this element is of very special construction (see Fig. 31) this should be returned to the factory for repair.

Restringing of Fin Types

In this case the process is similar except that the individual element strips must be twisted through 180° so as to lie flat-wise to each other directly under the place for the mirror. These element strips serve as supporting surfaces for the fin which is cemented in place with approximately 30% more section in front than in back of the center line of the assembly. This must be done with judgment so that the vane is in perfect balance the moment of the forward and rear sections must be equal. When finished, the forward edges of the ribbon should lie preferably along the edge of the cut-out section of the fin. Only a very little cement (a small bottle is supplied for cementing on the mirrors) should be used to attach the ribbon to the fin.

To Cement Mirror to Vibrator Ribbons

First inspect the mirror to be used for a clean front surface and unmarred silvering. If the front surface appears the least dirty, it should be cleaned as follows: Place the mirror face downward on a piece of fine tissue or lens paper, which should be on a smooth rigid surface, press the finger against the silvered surface of the mirror and move the mirror back and forth on the tissue paper to clean its front surface. Be careful to avoid touching the front surface of the mirror with the fingers. Insert the point of a toothpick on the small bottle of cement (supplied as a repair part) and coat thinly the outside surface of the vibrator ribbons, just half-way between the two ivory bridges. Moisten the points of a clean strip of paper, and touch it to the mirror edge, and then raise the mirror and place it, silver side against the ribbons and press the mirror against the vibrator ribbons firmly, also line it up evenly. With the sharp edge of a pen knife or razor blade, remove any excess shellac and finally dry the shellac by holding the point of the soldering-copper about an eighth of an inch directly below the mirror and vibrator strips for about one second.

This quick-drying process requires caution, as the mirror may be damaged, also, the soldering-copper must be held in such a position that the heat will be applied evenly to the shellac and not too close, or the shellac may boil out and get on the front surface of the mirror. If the mirror is still clean, the element is ready for service. The viewing surface of the mirror can easily be cleaned by placing the sharp edge of the razor blade in Xylene or better a toothpick in c.p. ether and then carefully scraping the mirror surface. As it sometimes requires

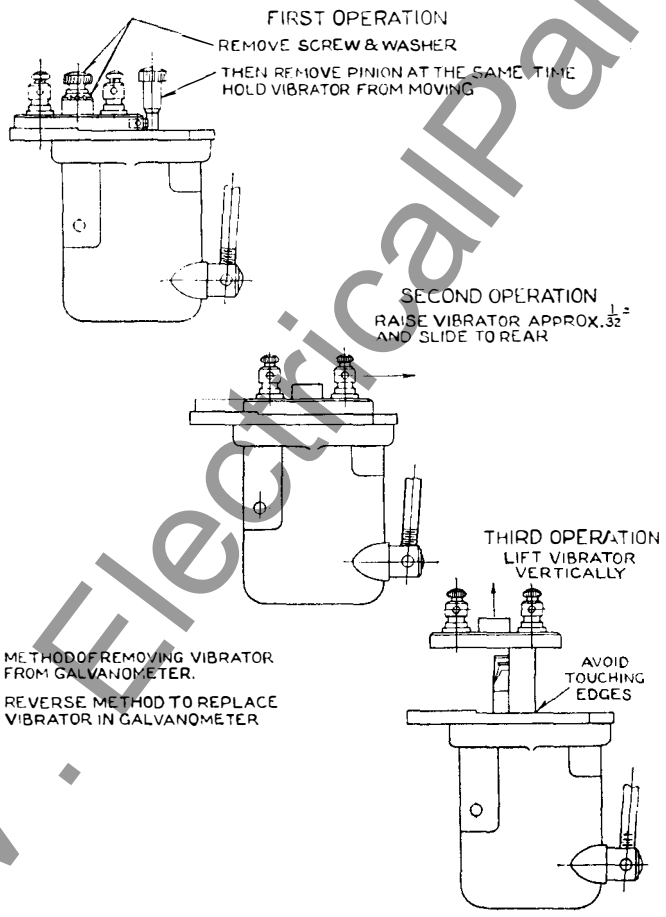


FIG. 33—THREE VIEWS OF A VERTICAL GALVANOMETER SHOWING THE STEPS TO REMOVE A VIBRATOR FROM THE MAGNET-WELL.

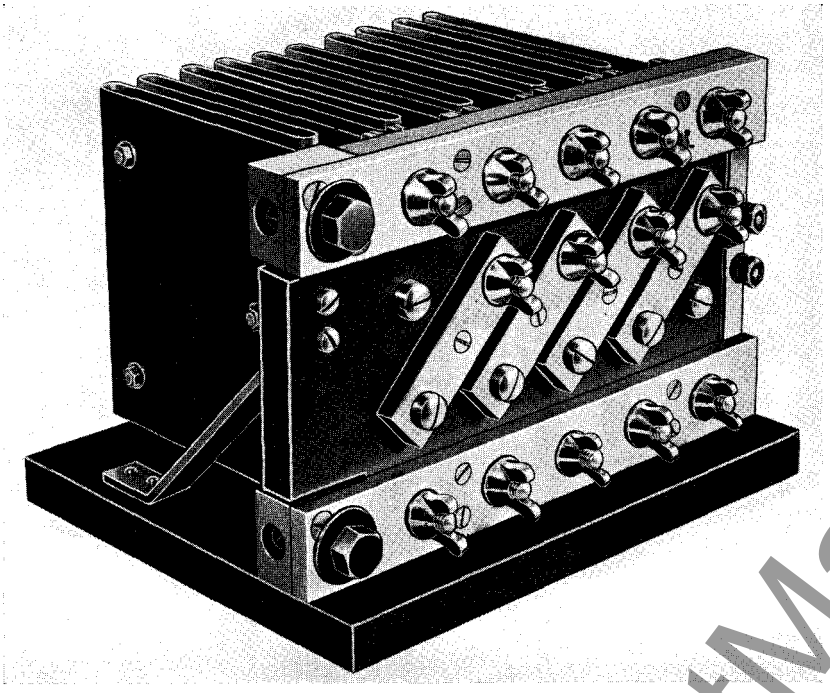


FIG. 34—NON INDUCTIVE SHUNT, 20 TO 1000 AMPERES.

practice to quickly dry the shellac with a hot iron, instead the operator may choose to leave the element in the open air for 15 or 20 hours to dry the shellac on the mirror. The quick-drying is considered the superior method, although the slow drying gives satisfactory results.

The completion of the above process should show a small but uniform bond of shellac around all four edges of the mirror. The under surface of the ribbon should have scarcely any shellac present except at the point directly behind the mirror where the ribbons almost touch.

All vibrators except the ultra-sensitive, polyphase average value and fin types follow the preceding instructions. In the case of the ultra-sensitive (although it is recommended it be returned for repairs) mirrors may be added provided the small magnets directly behind the mirror have not been disturbed in any way. The process is similar except that the mirror cannot be dried with an iron and **must be dried in air** as has been previously explained.

The polyphase average value is normally supplied with three mirrors, the two side mirrors being for use in the Osiso. When used with the PA oscillograph, the center mirror need be replaced only. This mirror is also dried in air.

The mirror is placed on the fin type so that it rests against the forward edge of the cut-out section of the fin or vane.

In cementing mirrors to all vibrators where the element strips carry current care should be taken to see that the silver surface of the mirror does not act as a short to the ribbons. A sudden change of sensitivity or element resistance may indicate this condition. A thin-pre-coating of cement before putting on the mirror will eliminate this condition.

OSCILLOGRAPH SHUNTS

Description

The shunts used in oscillograph work are either external or internal types. The latter have been described in connection with the half-length current control panel, S # 704222 and the half-length resistance control panel, S # 820094 both of which have self-contained shunts.

Non-inductive shunts of low capacity are furnished in continuous ratings from ½ to 25 amperes, as listed on page 50. Fig. 34 shows a non-inductive high capacity shunt for continuous ratings from 20 to 1000 amperes. All internal shunts and low capacity shunts, will stand 1000% overload for one minute without opening up, although they will be considerably damaged. The high capacity shunt, Fig. 34, will stand 1000% overload for one-half minute without opening up, but will also be damaged. All shunts will stand four times their rating for one minute without appreciable change in calibration.

Application

As the shunts are sufficiently non-inductive for measurements usually encountered in oscillograph work, they may be used over a wide range of frequencies. Studies up to 10,000 cycles may be made without difficulty. Their heavy capacity for overload permits their wide use in the testing of industrial equipment such as motors, welders, transformers, lighting devices, and circuit interrupting devices. Fig. 34-A shows a tabulated list of all shunts.

The low-capacity shunts are marked for their respective current and resistance

OSCILLOGRAPH SHUNT CHARACTERISTICS

TYPE OF SHUNT	CONTINUOUS RATED CAPACITY IN AMPERES	RESISTANCE IN OHMS	VOLTAGE OUTPUT AT RATED CURRENT	**MIN. RATING FOR 400% OVERLOAD WITHOUT CHG. CALIB.	**MIN. RATING FOR 1000%* OVERLOAD WITHOUT OPENING UP	VOLT-AMP. BURDEN OF SHUNT AT RATED CURRENT
Internal—Part of Current Control Panel S # 704222	5	.05	.250	1	1	1.25
Internal—Part of Resistance Control Panel S # 820094	1-5-25	.25-.05-.01	.250	1	1	.25-1.25 -6.25
External—S # 820154	.5-1.0	.50-.25	.250	2	1	.125-.250
External—S # 491700	2.5-5.0	.10-.05	.250	2	1	.625-1.25
External—S # 819940	12.5-25	.02-.01	.250	2	1	2.12-6.25
External—Series Parallel S # 492497						
1 Section Series	200	.0025***	.5***	1	½	100
5 Sections Series	200	.0125	2.5	1	½	500
5 Sections Parallel	1000	.0005	.50	1	½	500

* At this value damage to the shunt will occur.—**Rating in minutes.—***Approx. { exact values are engraved on shunt.

FIG. 34-A

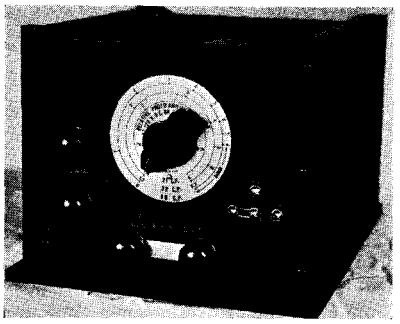


FIG. 35—D-C. INPUT AND LAMP-CONTROL PANEL VIEW OF THE LAMP AND MOTOR SUPPLY PANEL FOR THE PA OSCILLOGRAPH.

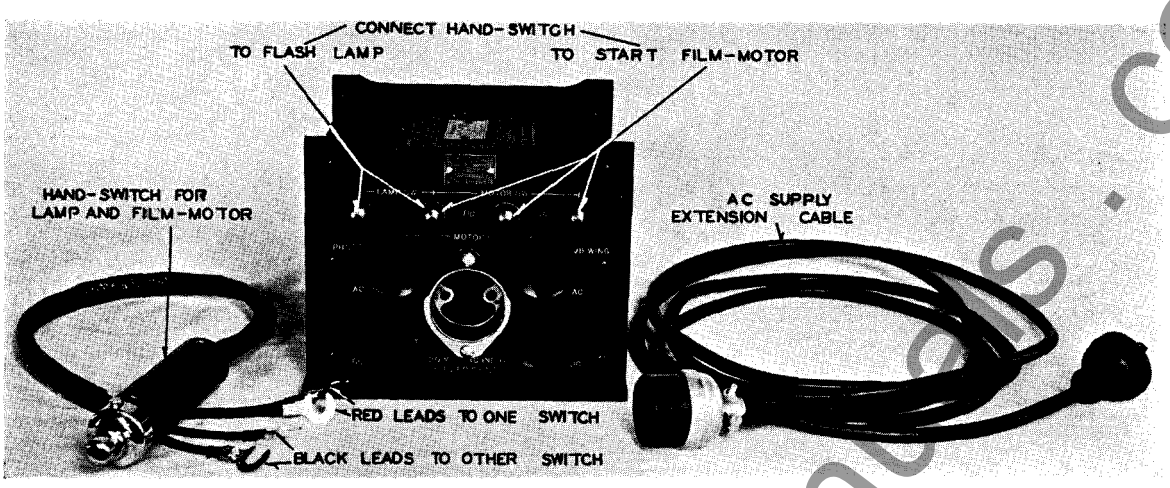


FIG. 36—A-C. INPUT AND MOTOR PANEL VIEW OF THE LAMP AND MOTOR SUPPLY PANEL, STYLE NO. 877043 COMPLETE.

ratings. The large 20-1000 ampere shunt S# 492447, Fig. 34, is not marked and reference to the table Fig. 34-A will have to be made. This shunt is made in five sections and may be connected in series, parallel or any combination of series parallel, by tightening the various wing nuts for the rating desired. The resistances per section, all five sections in series and all five sections in parallel, is stamped on the shunt.

All shunts are designed to withstand 5000 volts to ground.

Operation

To measure current the shunt should be connected as shown in Fig. 22-B and the circuit should always be calibrated with an ammeter.

Precautions to be followed in the use of shunts are discussed under the subject of measurements of current and voltage.

PANELS
Lamp and Motor Supply Panel S # 877043

Description

This panel is to be used on 120 volts a-c. at from 25 to 60 cycles or on 6 to 10 volts d-c. It contains the control of the voltage for the oscillograph lamp and means to plug in both viewing and film-holder motors for either a-c. or battery supply. The panel occupies the space in the front lower section of the PA Universal Oscillograph and is held secure by two screws fastened into base of the main case. The panel may be seen mounted in the oscillograph in Fig. 1. For details see Fig. 35 and 36, and the wiring diagram Fig. 37.

From the figures it may be seen that the panel consists mainly of a twelve to one reduction transformer which supplies the power to the lamp at a reduced voltage. The primary circuit consists of an input receptacle, two motor receptacle supply plugs and two terminal posts for a hand switch to control the filmholder motor. The secondary side has the lamp control potentiometer with two tap terminals, two motor receptacle supply plugs to be used for battery motors, and three pairs of terminals: one pair for the lamp supply, one pair for the battery supply input and the third pair for flashing the lamp during the photographic period.

Lamp Control for Viewing

Whenever the transformer is energized on 120 volts a-c., the secondary supplies current through the series resistance of the potentiometer which gives normal voltage to the standard single-filament 21 candle power automobile lamp (Westinghouse Mazda 1129). Or when using either the 32 c.p. or the 50 c.p. lamps (Westinghouse Mazda 1133 and 1183 respectively), set the tap link on

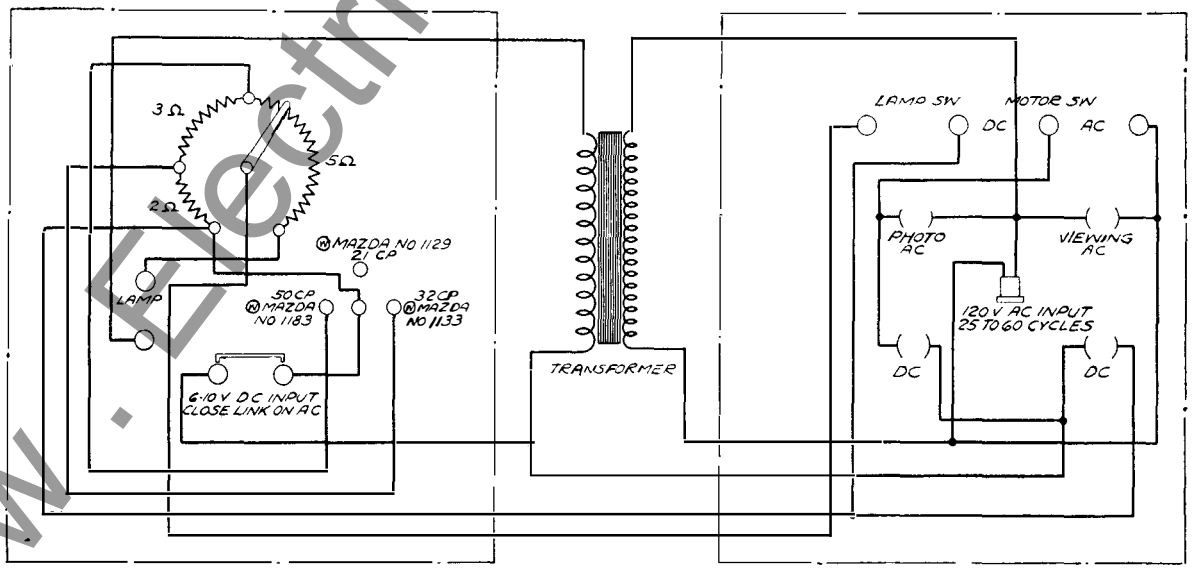


FIG. 37—WIRING DIAGRAM FOR THE LAMP AND MOTOR SUPPLY PANEL, STYLE NO. 877043.

the panel to the screw tap engraved 32 or 50, then the series resistance is cut down to give normal voltages to the two lamps respectively. These normal voltages, thus obtained, are used for continuous duty on the lamps when viewing or when adjusting the various circuits and galvanometer spots. In other words, these taps on the potentiometer, when used with the corresponding lamp, give the most efficient operating light for viewing.

Lamp Control for Photographing

During the short periods of photographing, a higher voltage is applied to the lamp. This increased voltage applied during photographing depends on the speed of the record or the writing speed of the galvanometer light beam. The maximum writing-speed is the maximum lineal travel of the beam path on the film per second. The amount of voltage applied to the lamp is arbitrary for any film speed, but for equal contrasting records, it requires more voltage the higher the writing speed. The exposure time must be taken into consideration to avoid burning out of the lamp. The voltage to the lamp during the photographic period is controlled by the movable point on the potentiometer and is set by the dial knob. This movable point on the potentiometer is brought out to a set of binding posts which are on the opposite side of the panel or oscillograph and engraved LAMP SW. These terminal posts must be shorted together during the photographing period to put increased voltage on the lamp for that period. This is done by a hand switch when using the continuous drive filmholders and by an automatic switch on the drum filmholder. (See discussion under filmholders). The amount of voltage applied to the lamp is controlled by the setting of the dial knob. The dial is engraved with arbitrary numbers which show the relative photographic ability or points of equal intrinsic brilliancies for each of the three lamps when used with regular orthochromatic film. In other words, the corresponding figures for each lamp indicates the position of the dial knob to obtain equal contrasting records for each of the various lamps.

For setting the relative photographic quality of the lamp this dial was calibrated with 120 volts a-c. input on the primary of the transformer or 10 volts d-c. battery input. The battery must be fully charged or backed up with a charger. With either of the above inputs applied, the life of the lamp will be great enough to photograph for periods in the order of minutes for all positions of the dial knob for all the lamps except when using the 50 c.p. lamp. When using the 50 c.p. lamp, the section engraved DANGER gives a voltage to the lamp such that its corresponding life is of the order of seconds or fractions of a second. The dial knob can be placed in the DANGER section when using the drum filmholder for high-speed pictures only where the lamp is flashed for intervals of less than $\frac{1}{5}$ second.

Motor and Control

On the a-c. input panel side are four receptacle plugs, two on either side of the input receptacle. The two toward the rear of the oscillograph engraved VIEWING are used for the viewing motor supply and the front two for the filmholder motor. The top in either case is for 120 volt motors and the bottom two for 6 volt d-c. motors. In the case of the viewing motors the connections are made by inserting the motor supply cable, in its corresponding outlet. The filmholder motors are controlled by the same hand switch which also flashes the lamp. To use this hand switch, connect a pair of leads of one color to the lamp switch terminals and the other colored pair to the motor switch terminals. When using a battery supply, one terminal will be common with the switch to which one red and one black lead will be connected. If a drum filmholder is used, the lamp switch is operated through the filmholder mechanism. It should be noted that motors will only run on their designated voltages. If 6-10 volts d-c. is used, the 120 volt a-c. motors must be replaced with the correct d-c. drive. (See discussion under filmholders.)

Battery Input

A battery voltage of either 6, 8, or 10 volts may be connected to the panel to supply the lamp and motors. Although 6 volts will give satisfactory results for the slower film speeds, ten volts is recommended as the lamp resistor dial as it is calibrated for this input voltage.

To connect for battery input to the motors and lamp, remove the link connected across the input terminal posts engraved 6-10 V. d-c. INPUT on the left side of the control panel and connect heavy battery leads. These leads should be the equivalent or less than 4 feet of #10 B. & S. gauge wire or 10 feet of #6 B. & S. gauge wire. (Westinghouse battery cables S #724758 are made for this purpose.) The battery should not be less than a 100 ampere-hour battery, an "Exide" 12 volt bus or automobile battery will do. Almost any "heavy-duty" automobile battery with either two six volts each or one twelve volts will meet most test requirements. In using a 12 volt battery, the panel is connected across 10 volts only. This leaves one cell of the battery not in use. If weight is an important feature, batteries with one cell cut-out will be supplied by "The Electric Storage Battery Company, New York, thus giving a 10 volt battery. A battery of sufficient capacity made up by cutting out one cell will weigh about 75 pounds and the above company's type is known as "5-cell XHR-13".

The battery should be kept fully charged, or preferably backed by a charger and should be set to give sufficient charge to give a battery output voltage of about 10 per cent higher than the normal. A standard 1 to 6 ampere Rectox charger, S #971502 is recommended for most laboratory oscillograph applications, also see notes on page 28.

115 Volts D-C.

To operate the oscillograph from 115 volt d-c. source, it is recommended to use a d-c.—a-c. inverter—taking the alternating current and apply it to the panel in the usual way. The regular 120 volt filmholder or viewing motors will operate very satisfactorily from 120 volts—d-c. source but an inverter is quite necessary to supply lamp voltage efficiently and satisfactorily. It is difficult to control the lamp voltage with a series resistance.

The d-c.—a-c. inverter recommended is: 5A Frame—S #578137 for 120 volts d-c. It is rated at 250 volt-amperes output at 3600 rpm.

Hand-Switch

This switch is a double circuit switch and is used to simultaneously initiate the filmholder motor and to flash the

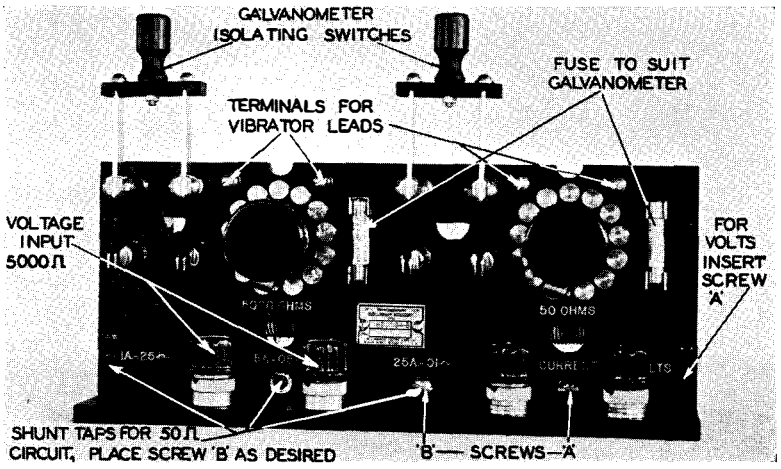


FIG. 38—HALF-LENGTH CURRENT AND VOLTAGE RESISTANCE-CONTROL PANEL STYLE NO. 820094, WITH GALVANOMETER SWITCHES OPEN AND ARROWS SHOWING DETAILS.

lamp to photograph the record. The red leads are connected to one switch and the black ones to the other. The switch can either be allowed to lock itself closed or if the locking button is held in, then the film motor will stop upon releasing the main push-button. The cable that comes with the switch has a pair of red leads to one switch and a pair of black to the other switch.

Relay Initiation

An external connected relay to this panel in place of the "hand-switch" may be used to initiate the oscillograph by flashing the lamp and starting the film motor. The closing of the relay contacts will complete the circuits to the panel binding-posts to start the film motor and short the lamp resistance. The relay should be near the oscillograph and the actuating power to the relay may be either voltage or current and be controlled at a remote point, if desired. For ordinary work, a relay similar to a two-circuit closing type SG (S # 837265) is recommended.

This relay is for 120 volts 50 or 60 cycles. For 25 cycles 120 volts use relay S # 837263 and 120 volts d-c. use relay S # 837262. These relays are the panel-mounting type.

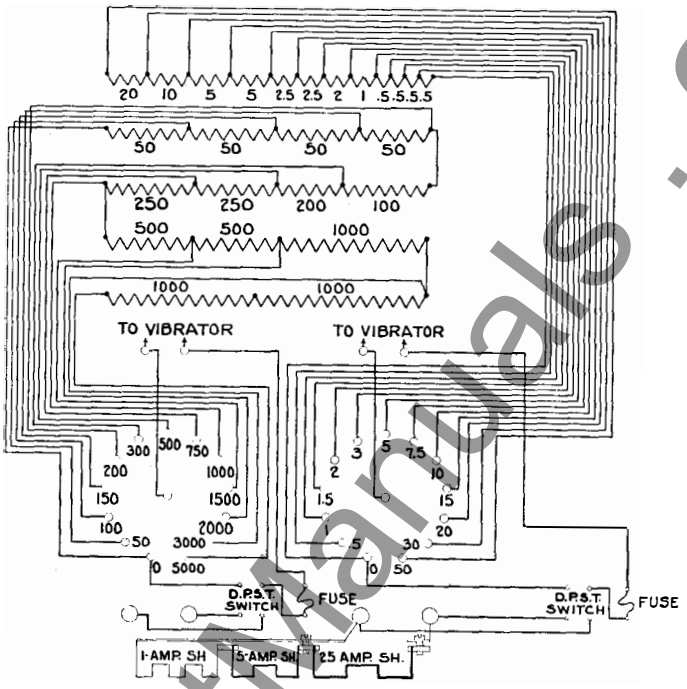


FIG. 39—WIRING DIAGRAM FOR THE HALF-LENGTH CURRENT AND VOLTAGE RESISTANCE CONTROL PANEL.

Half-Length Current and Voltage Resistance Control Panel S # 820094

Description

This panel shown in Fig. 38 consists of a 5000 and a 50 ohm variable stepped resistance used for measuring voltage and a multiple current shunt with a range of 1, 5 and 25 amperes. It has convenient circuit connecting terminal posts with large insulated nuts. There are double-pole single-throw switches for the purpose of completely isolating the galvanometer from the input terminals.

The resistance sections are of negligible inductance to 10,000 cycles per second. The reactance of the 5000 ohm section gives one per cent increase in resistance at 10,000 cycles as compared with direct current. Each resistance step is held within 2% of the engraved value for the 5000 ohm unit and 3% for

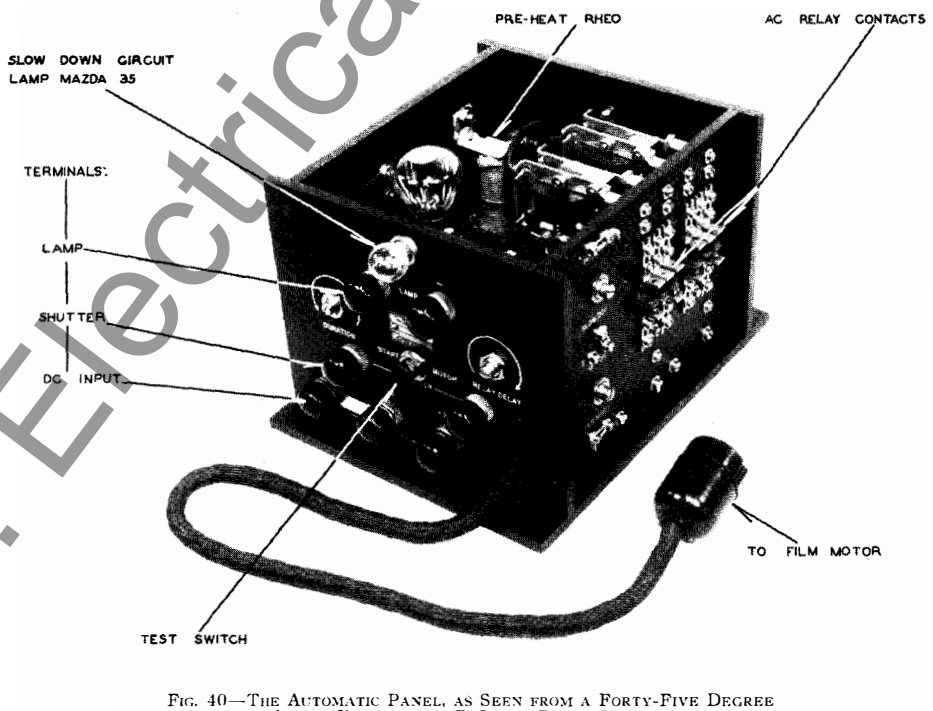


FIG. 40—THE AUTOMATIC PANEL, AS SEEN FROM A FORTY-FIVE DEGREE ANGLE, VIEWING THE D-C. AND RELAY PANELS.

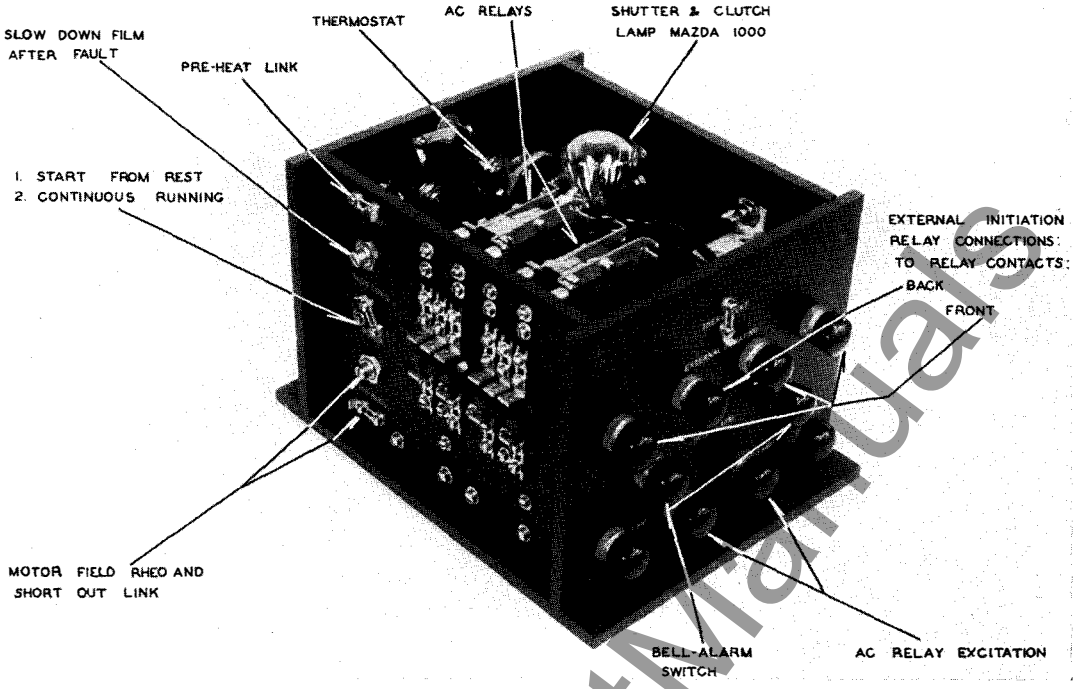


FIG. 41—SAME AS FIG. NO. 40 EXCEPT VIEWING FROM THE OPPOSITE SIDE AT THE A-C. AND RELAY PANELS.

the 50 ohm unit. The high and low resistance units are tested to withstand 5000 volts between each other.

The continuous current-carrying capacity of any part of the 5000 ohm section is .2 amperes which is equivalent to 1000 volts with all the resistance in. The continuous current-carrying capacity of the 50 ohm section is ¾ ampere, even though no vibrator elements will carry ¾ ampere without damage.

The current shunts are designed to carry their rating continuously. They will withstand ten times normal or 1000% overload for one minute. (See Fig. 34-B.)

The panel fits into the oscillograph as shown in Figs. 1 and 4. The wiring diagram is shown in Fig. 39.

Application

Because of the above characteristics, this panel was designed for giving voltage or current control for the galvanometers on alternating or direct current. The stepped resistance control provides a means of obtaining proportionality of deflections by merely comparing the values of the steps.

This panel extends the laboratory range of the PA oscillograph by supplying the control for the measurement of voltages up to 1000 volts and currents up to 25 amperes continuously. The 1000% overload rating for one minute permits the current sections to be used during the photographic period only where normally external shunts would be required. The non-inductive feature of the voltage control also permits measurements to be made on other than commercial frequencies and particularly those found in the radio field, as for instance, audio amplifiers.

Operation

The galvanometer leads are connected to the two small screw terminals immediately above either resistor dial. The galvanometer to which each resistor is connected and its polarities may be traced by the colored leads supplied with the oscillograph case. In making connections to the galvanometers one must be sure the proper fuse for that galvanometer is in its corresponding resistor control unit. For fuse reference see "Galvanometer Characteristics Table", Figs. 9 and "Oscillograph Fuse Characteristics", Fig. 22-A.

The initial series resistance (see wiring diagram Fig. 39) to be used should be determined so that the safe current-carrying capacity of the elements is not exceeded. This may be obtained from the description under the headings of each vibrator element or galvanometer. Also see the Beam Deflection Table, Fig. 18.

A multiple shunt is assembled in the panel and is connected in parallel with the 50 ohm step resistor. By changing the screw "A" from the hole engraved, "Volts" to the hole engraved, "Current" on the front of the panel, see Fig. 38,

CURRENT INITIATION—25 CYCLES

Upper Gap Inches	Percent of Rated Current Closing	Percent of Rated Current Dropout	Time in Cycles at 4 Times Closing Current
.031	83	55	.24
.050	102	55	.25
.060	112	55	.26
.075	130	55	.27

CURRENT INITIATION—60 CYCLES

Upper Gap Inches	Percent of Rated Current Closing	Percent of Rated Current Dropout	Time in Cycles at 4 Times Closing Current
.015	60	49	.37
.020	65	49	.40
.031	83	49	.43
.040	100	49	.45
.050	110	49	.48

FIG. 42

and wiring diagram, Fig. 39. The capacities of the multiple shunt are 25, 5 and 1 amperes which give a 250 millivolt drop at the rated current. The desired shunt rating is obtained by placing screw "B" firmly in one of the screw holes provided as the engraved capacities indicate on the panel front.

Automatic Operation Panel S #877042

For the Automatic Oscillograph only (Battery Operated)

Description

This panel is designed to operate on low voltage d-c. and contains the control for putting the "PA" Automatic Oscillograph into photographic operation immediately upon the appearance of an abnormal condition in a power system due to some fault or disturbance. The panel occupies the space in the front lower section of the oscillograph, see Figs. 52 and 54. This panel is held secure in the main case by means of two screws through the panel and tapped into the base of the main case.

This panel contains two a-c. relays, one of 1 ampere and the other 5 ampere rating for fault initiation, two d-c. relays for control and a thermostatic time limiting device for giving a predetermined time of operation after the fault has cleared. There is also present the current limiting resistor lamp for the heat resistor. The galvanometer lamp recommended for automatic operation is #1129, 21 c.p. Westinghouse Mazda Lamp. There are various control resistances for setting the motor into operation either with or without the magnetic clutch. There are terminals for connecting external fault relays and for the use of a bell alarm. The schematic wiring diagram, Fig. 43, illustrates these various functions. For a descriptive picture of the automatic panel see Figs. 40 and 41.

Application and Operation

The operation sequence of the automatic panel when connected through the negative phase-sequence current network panel is as follows: Say for example, a line-to-ground fault occurs on the transmission line, the one-ampere initiating relay closes due to negative phase-sequence current from transformers in the transmission line. The one-ampere relay in closing its contacts shorts out the pre-heat resistance to put photographic brilliance on the lamp, opens the shutter to admit the galvanometer beams to the photographic surface, and closes the clutch which puts the photographic surface into motion. These three operations follow the closing of the initiating relay simultaneously, and hence the photographing of the faulty electrical quantities is under way within the first 60 cycle wave after the appearance of the fault. The panel will keep the oscillograph in operation as long as the unbalanced fault load is sufficient to keep the one-ampere relay closed on negative phase-sequence current. The initiating relay will drop-out at about sixty per cent of its minimum closing value, but the oscillograph will continue to operate for a predetermined period which is controlled by a thermostatic circuit. This continued photographing period, after the relay drops out, is to allow for stabilization of the system. The length of this period is adjustable to suit the time characteristic of the power line, or particularly the stabilization of synchronous equipment and is adjusted by means of a rheostat engraved, "DURATION". This time period ranges from a fraction of a second to 10 seconds.

This duration or period after fault is obtained by the closing of two 6 volt d-c. holding relays operated from the contacts of the "initiating relays". When closed, these relay contacts parallel the contacts of the initiating relays and carry the whole of the operating load when the latter drops out. Also, when the initiating relay opens, its back contacts close the thermostatic circuit which puts battery current through the thermostat at a rate predetermined by the setting of the "duration" rheostat.

There is another feature surrounding this duration period after fault and that is a relay delay circuit to avoid these "holding relays" from locking in on the many short current surges such as switching surges and avoids the use of film unnecessarily. This "relay delay circuit" is adjustable from immediate closure of the "holding relays" to a sixth second or more after the closing of the "initiating relays". This delay is adjusted by means of a rheostat engraved, "RELAY DELAY". The rate of delay is obtained by controlling the rate of current flow through a miniature lamp (Westinghouse Mazda #35) mounted on the battery input side of the panel. In other words, the rate of heating up of the miniature lamp controls the potential across one "holding relay" and hence controls its closure. (See wiring diagram Fig. 43.)

A-C. Panel on Right-Hand Side

Fig. 41 shows the a-c. side of the automatic panel. The four terminals engraved, "EXTERNAL INITIATING" over them and numbered 1, 2, 3, and 4, are connected to the closing contacts of the internal initiating relays. These terminals are brought out to operate the oscillograph from externally mounted relays of any desired number which must have their closing contacts connected in parallel and to these four terminals. When closed, the four terminals are shorted together by the relay. A link may be placed across posts 1 and 2 by using only three closing contacts on the external relays provided only—6 volts are used on the motor armature, as described below. To operate the thermostat properly the link engraved, "THERMOSTAT" must be opened and a series connection made through a contact on every external relay. Two terminal posts for "bell alarm" are brought out in a position just below the external initiating terminals. These terminals merely connect the bell circuit to the initiating terminals to act as a switch to ring the bell. The bell must receive its energy externally or one side of the bell may be connected to the 6 battery post and the other side connected to the right-hand bell terminal (the left-hand bell terminal open) and thus ring the bell from the battery source.

Below the bell alarm terminals are two pairs of terminals for the internal initiating relay coils. These terminals are to be connected in the secondaries of the initiating circuit current transformers. The impedance of the one-ampere relay coil is 0.42 ohms when the relay is open, and 0.67 ohms when the relay is closed; the five-ampere relay coil is 0.015 ohms open and 0.020 ohms closed. Both impedances taken on 60 cycle current by the volt-ammeter method at rated currents.

Relay Panel Inside and Front

The initiating relay contacts can be seen projecting from the internal panel toward the front of the oscillograph shown in Figs. 40 and 41. Each relay has five stationary contacts mounted on the panel wall, (three front and two back contacts.) Each contact is held in position by means of two screws tapped into the panel. The vertical position of the contact is adjusted by loosening these screws and sliding the contact up or down. The upper or the stationary closing contacts are adjusted at the factory to give about a 0.010 of an inch bend in the spring of the closing contacts of the relay when closed. That is, in measuring the gap between the contacts, the measurement of the gap of the front contacts while the relay is open and is about 0.010 of an inch more than the measurement of the back contact gap, while the relay is closed. The contact opening is controlled by adjusting the position of the lower stationary contacts **only.** And this should be the only adjustment necessary. By the adjustment of this contact opening, the current required for closing is obtained. The two tables, Fig. 42, give the approximate gap settings to obtain the desired closing currents—given in per cent of panel engraved currents.

The contact gap settings can be made very small, just enough to open the back contacts is all that is necessary to break the circuit for there is but 6 volts across any of the contacts. It is more practical to use smaller contact-gap settings on 60 cycle initiating than on 25 cycles as the drop-out current is smaller on 60 and the chatter is less. Small gap settings are desirable, as the closing time is shortened and hence the overall initiating time for the oscillograph to be put into photographic operation is shortened proportionally. The operator must be cautioned against **moving the laminated field poles, for the slightest movement of these poles** will upset the seating of the armature and cause chatter in the relay and it may require the return of the relay to the factory for readjustment.

To the left of the initiating relay contacts are three links and two variable

rheostats. The top link, engraved "PRE-HEAT", when closed connects lamp for photographing in series with the pre-heat resistance and across the battery to give slightly sub-normal voltage across the galvanometer lamp. During the photographic period this series pre-heat resistance is shorted out by the initiating and holding relays and give full voltage across the lamp. The lamp used in this manner should be replaced about once a month, (read discussion—Lamp Assembly under section on "Main Case".) to be sure the lamp does not burn out and cost the loss of a record. Just below the pre-heat link is a variable rheostat engraved "SLOW DOWN". This rheostat connects to one side of the battery and the other side of the rheostat connects through the "motor link" when in position No. 1, and then through motor armature to the other side of the battery. As long as the initiating relay is closed this "slow down" rheostat is shorted out. But as soon as the initiating relay opens, this rheostat becomes effective, causing the motor to slow down to a speed as preset by the rheostat. The purpose is to conserve film for the stabilization period after fault for that part of the record. The motor link in position No. 1 is used only with motors without a magnetic clutch. The motor armature stationary, the field is excited, at the time of fault, the armature field is energized and drives the film starting from rest.

When a magnetic clutch is used the "motor link" is placed on position No. 2 which connects the motor armature directly across the battery continually. The closing of the initiating relay energizes the clutch to start the film. The "slow down" rheostat is not brought into use when the motor link is on position No. 2. The field rheostat will adjust the motor speed regardless of the position of the motor link and the link under the field rheostat merely shorts out the field rheostat to assure full field on the motor.

Below the initiating contacts, the mounting screw heads for the "d-c. holding relays" are shown. The contacts for these relays are accessible through openings in the base directly below these mounting screws. The relay has a plunger with a silver disk to short out the contacts. If the oscillograph is used in a warm sulphur atmosphere or in the neighborhood of rubber, this silver disk should be polished at intervals. The gap settings of these relays are adjusted at the factory to operate properly when the battery is fully charged or backed up by a charger. If the battery supply is allowed to get in a discharged condition, these relays will not close.

D-C. Panel on Left-Hand Side

(E). On this panel, (See Fig. 40) are shown the small relay-delay lamp at the top (Westinghouse Mazda #35), two terminals for the lamp lead connections, the "duration" and "relay-delay" resistance adjustments (for description of operation see Section under application and operation, the shutter lead connections, push button switch in the center, and the battery lead connections and the filmholder cable extension at the bottom.

The push button switch enables the operator to test the outfit. This switch closes all circuits and opens the thermostatic circuit. The switch is closed to run off the film-leader in loading the film-holder and to inch up the film at any time. It also lights the lamp and opens the magnetic shutter enabling the operator to observe the galvanometer light spots on the calibration window to give them their final adjustment.

Ordinarily, the battery is connected to the plus (+) terminal and to the terminals engraved — 6 and — 2 — 12 are linked together. The battery cable required should be similar to the one supplied in which each lead is equivalent to 4 feet of No. 10 B. & S. gauge wire or 10 feet of No. 6 B. & S. gauge wire. It is recommended to always back the battery with a charger delivering a charging current sufficient to keep the terminal voltage between 6.5 to 6.6 volts. The battery should be floated continuously across the charger which can be adjusted to supply current a little in excess of the oscillograph drain. The terminal voltage should be checked and the battery inspected at regular intervals of about two weeks. The charging current should be carefully adjusted so that the proper voltage is maintained.

The storage battery recommended is a standard 6 volt automobile battery having a capacity of not less than 100 ampere-hours. Since the current drain for the high-speed oscillograph with clutch is about 5.5 amperes using the #1129 or 21 c.p. galvanometer lamp and for the low-speed PA oscillograph is 1.5 amperes (the latter current is the motor field only, while the former includes the preheat lamp and the idle continuously running motor current), the standard Westinghouse 1 to 6 ampere Rectox charger S #971502, transformer insulated, is recommended. If higher than the 6 ampere drain is required, then a charger of larger capacity is necessary.

If other film speeds other than those obtainable from the 6 volt battery, as described under the division on filmholders, the connecting link between

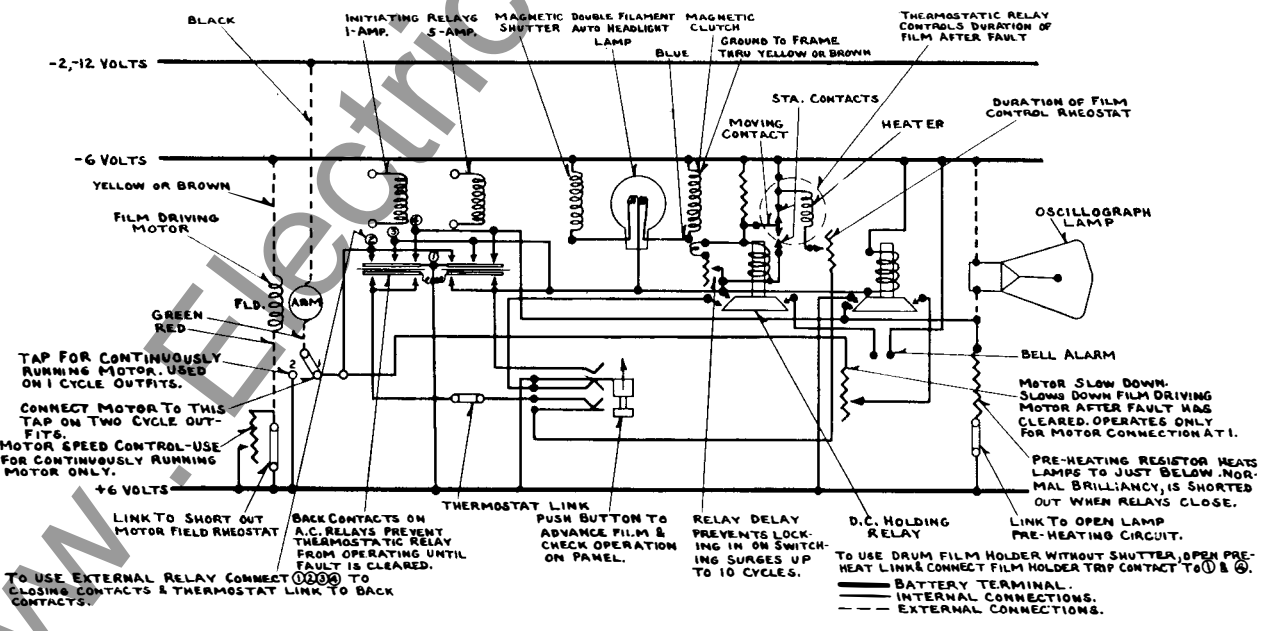


FIG. 43—AUTOMATIC PANEL SCHEMATIC WIRING DIAGRAM.

binding posts — 6 and — 2 — 12 is removed. Six volts is connected between posts plus (+) and — 6 and an extra lead from post — 2 — 12 is connected to varying points of the regular battery plus a similar battery in series with it to give 12 volts. This extra lead is connected to the 12 volt battery bank at any point to give the desired film record speed. This film speed is determined by a stop watch and the film length recorder on the holder.

Inside Rear Panel

(F). To this side of the automatic panel are mounted the pre-heat resistor, and the magnetic shutter, clutch, and double filament lamp, as may be seen in Figs. 41 and 40. The pre-heat resistor is connected in series with the photographic lamp to limit the voltage to the lamp so as to increase its life but keeps the lamp heated to such a value so that it can come to a photographic brilliancy in the minimum time required to comply with the initiating speed of the rest of the apparatus.

This "double-filament" lamp is the standard 32 c.c. automobile lamp (Westinghouse Mazda #1000). This lamp is a speed-increasing device. The magnetic clutch is connected in series with one of the double filaments of the lamp and the magnetic shutter in series with the other. (See wiring diagram Fig. 43, also see discussion under subjects "Magnetic Shutter" and "Magnetic Clutch"). The surge current of the lamp is ten to fifteen times its normal current. This surge current gives a quick snappy closing action to the clutch and a similar opening to the shutter. The operating current of the lamp is sufficiently large to keep both the clutch and shutter in their operating positions. Inasmuch as this lamp has the shutter and clutch coils in series with its filaments and also since it is in service only during the photographic period, the life of the lamp will last through long periods, perhaps several years.

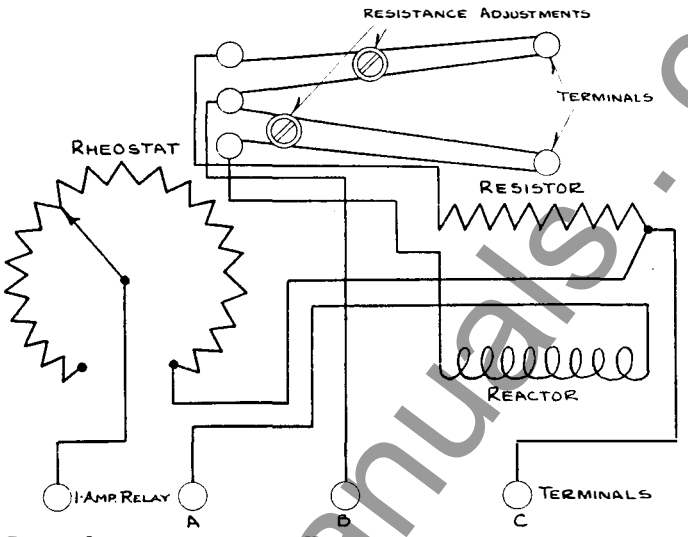


FIG. 45—INTERNAL WIRING OF THE HALF-LENGTH POSITIVE OR NEGATIVE PHASE SEQUENCE CURRENT NETWORK PANEL.

Half Length Positive or Negative Phase-Sequence Current Network Panels

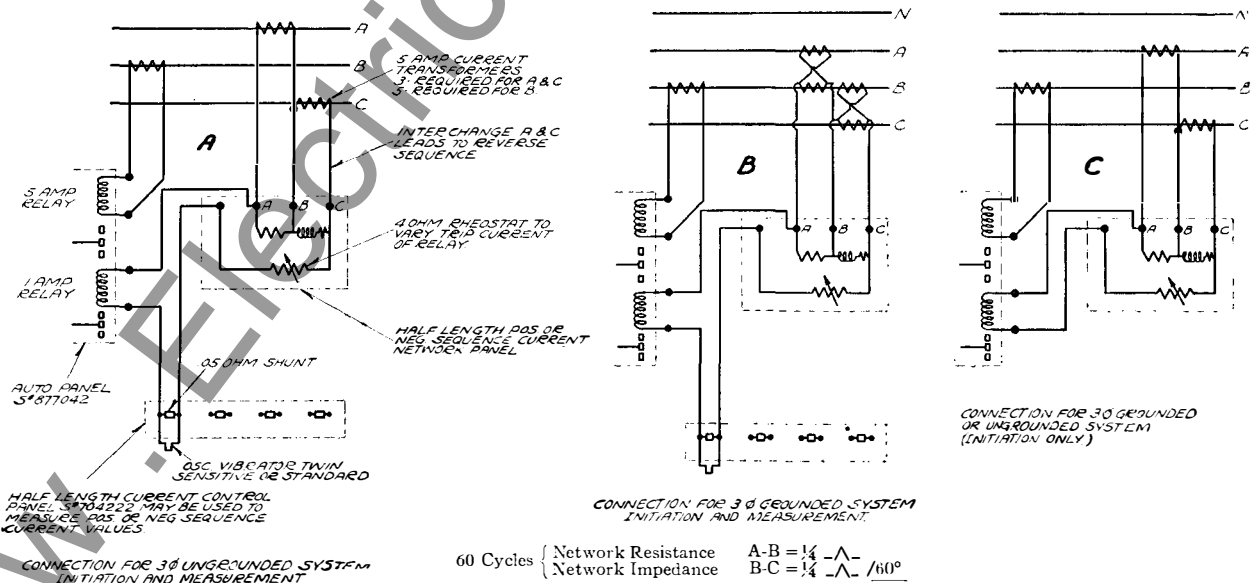
Description

This panel shown schematically in Fig. 44 consists of a phase-sequence current network, an adjustable slide-wire resistance for balancing the network and a variable resistance for controlling the initiating value of the 1-ampere network relay used with the panel for negative phase-sequence current initiation. It fits in the oscillograph under the galvanometer compartment as shown in Fig. 4.

The panel as designed can work only on the frequency specified. The 50 cycle panel is S#877608 and the impedance values are approximately 5/6 of those for 60 cycles as given under operation. The corresponding panel for 25 cycles is S#109638 and the impedance values are approximately 25/60 of those for 60 cycles.

Application

This panel is connected in series with the 1-ampere relay in the automatic panel to initiate the oscillograph on all unbalanced faults on a single feeder, and with the 5 ampere relay energized from the current from any line of the same feeder, the oscillograph is initiated into photographing activity for any abnormal current either balanced or unbalanced due to fault or disturbance.



60 Cycles { Network Resistance A-B = ¼ -/\- / Network Impedance B-C = ¼ -/\- /60°

FIG. 44—WIRING DIAGRAMS FOR CONNECTING THE "HALF-LENGTH POSITIVE OR NEGATIVE PHASE-SEQUENCE CURRENT NETWORK PANEL" TO INITIATE THE AUTOMATIC OSCILLOGRAPH ON UNBALANCED FAULTS AND TO GIVE POSITIVE OR NEGATIVE SEQUENCE CURRENT INDICATIONS ON THE GALVANOMETER.

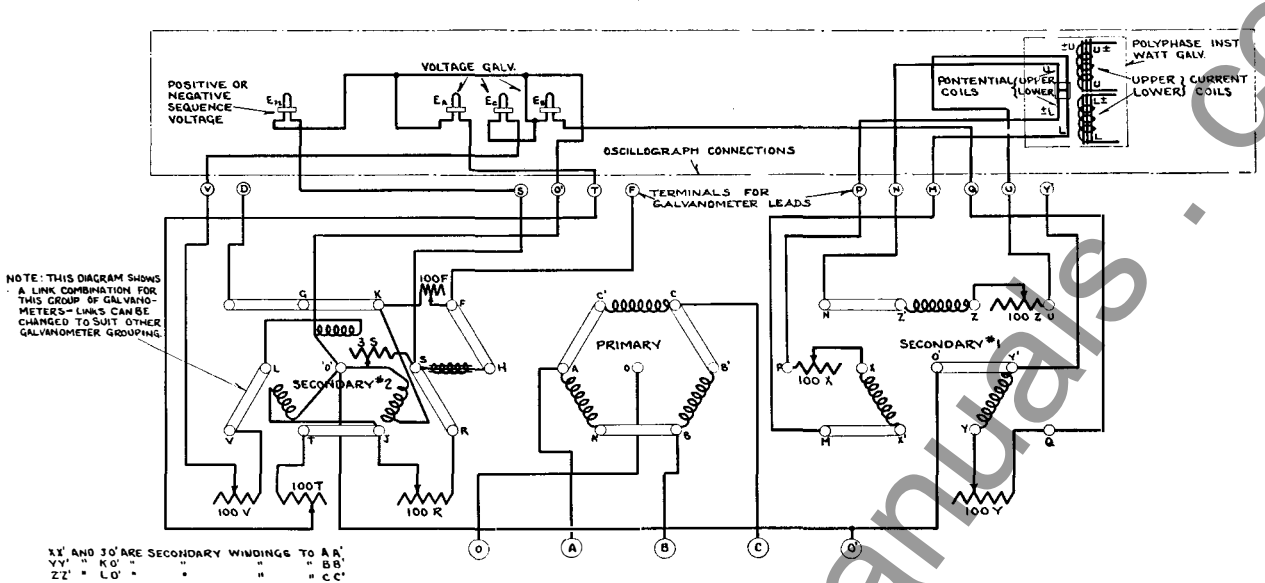


FIG. 46 — SCHEMATIC WIRING DIAGRAM FOR THE "FULL LENGTH POTENTIAL CONTROL PANEL" SHOWING THE PANEL LINK POSITIONS AND THE GALVANOMETER LEAD CONNECTIONS TO FIVE ELEMENTS TO INDICATE A SEQUENCE VOLTAGE, THREE LINE VOLTAGES, AND THE VOLTAGES TO THE POLYPHASE INSTANTANEOUS WATT GALVANOMETER.

Operation

The network in the panel is adjusted for 60 cycle current from the regular instrument current transformer. The resistance leg of the network is ¼ ohm and the reactance leg is a 60 degree coil of a constant ¼ ohm impedance. The coil is wound on an open core which avoids saturation and keeps the coil reactance constant on heavy overloads. A similar panel is available for use on 50 and 25 cycle systems.

The network is very carefully balanced and can be relied upon for positive or negative phase-sequence current measurement as well, by means of the galvanometer energized from a shunt. The shunt is connected in the output circuit of the network and in series with the 1-ampere relay, see Fig. 44 parts A, B, and C.

Fig. 44 part A shows the schematic wiring connections of the network panels, the relays in the automatic oscillograph and the shunt and galvanometer on a three-phase, three-wire ungrounded system. This connection will give the initiation and measurement of negative sequence current. Fig. 44 part B shows the same apparatus connected to a three-phase, four-wire or grounded system. This connection requires two extra transformers connected cross-wise as shown to balance out zero sequence currents from the network and hence the initiating relay and galvanometer. It may be desirable to initiate the oscillograph on both negative and zero phase-sequence, in some instances. In this case, the galvanometer initiation would be of little value, see Fig. 44 part C for connections.

For positive sequence current initiation or measurement, the same connections apply except the two network legs are interchanged by interchanging the leads from A and C lines at the panel. In this case, however, a 5-ampere relay is required instead of the 1-ampere relay.

Calibration

For correct adjustment of the network, noted by the galvanometer deflection, there will be no deflection on the negative phase-sequence connection, when the currents in all three phases are balanced. If the network is out of adjustment, it can be corrected by carefully holding the three-line currents very constant, at the same time moving the two slide-wire adjustment screws inside of the panel, see Fig. 45. First one, then the other, may be moved several times until the galvanometer gives no deflec-

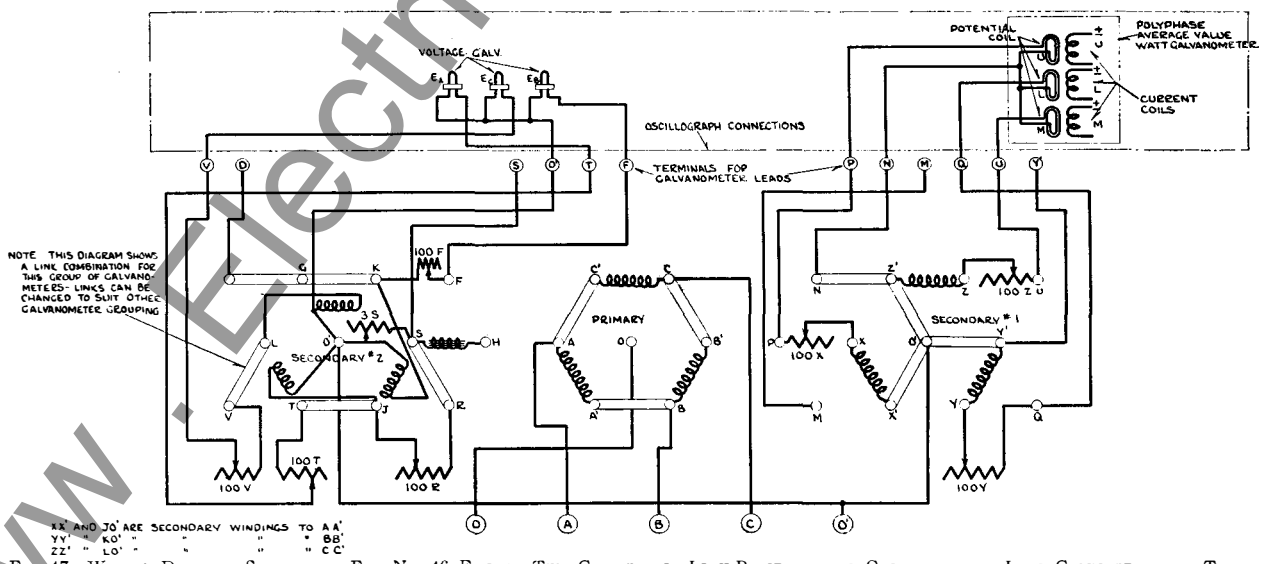


FIG. 47—WIRING DIAGRAM SIMILAR TO FIG. NO. 46 EXCEPT TWO CHANGES IN LINK POSITIONS AND GALVANOMETER LEAD CONNECTIONS TO THREE VOLTAGES AND THE THREE VOLTAGES TO A POLYPHASE AVERAGE WATT GALVANOMETER. WIRING INDICATED FOR NUMBER 2 GALVANOMETER POSITION.

tion. Care should be taken to note that extraneous fields or the presence of large quantities of iron or metals can upset precise calibrations and sometimes it may be necessary to calibrate the network where it is to be applied.

For further information concerning the use of phase-sequence networks for metering and relay operating refer to Bibliography, No. 8 to 13.

Full Length Potential Panel

General

The "Full Length Potential Control Panel", S # 569048 is especially designed for use with the automatic oscillograph on electrical power system study. It occupies the full panel space on the lower left side of the oscillograph. The panel contains a bank of three single phase potential transformers which reduces the voltage from 120 to 0.6 volts over a frequency range of from 25 to 60 cycles per second. The panel can be used to control the potential to the galvanometers from the following systems: three phase three or four wire, two phase three wire, two phase four wire, three separate single phases, or any single phase. With the link system on the panel front, many combinations of connections can be made. Figs. 46 and 47 show two schematic wiring diagrams of the panel with a common connection to control the voltage to the galvanometers. The front panel view is shown in Fig. 43. A detail wiring diagram is supplied with the panel.

Description

With reference to the above figures of this panel, the primaries of each of the three potential transformers are connected to the screw-driver terminals and links in the center of the panel front. The three insulated thumb-nut input terminals A, B and C are connected to the center panel terminals A, B and C, thence to the three transformer primaries. The other side of the primaries are connected to the panel center terminals A^1, B^1 and C^1. The ground terminal O is connected to the center screw-driver terminal O of the panel front to allow the transformer primaries to be connected in either star or delta for use with three phase four wire and three phase three wire systems, respectively. By properly grouping the primary and secondary windings of these transformers, single phase or two phase three and four wire systems may be studied.

To connect a two phase three wire system use posts input terminals A, B, and O. The panel links are connected A^1O and B^1O. The third link is open. The secondary connections in each case are left up to the operator's discretion.

For two phase four wire systems use input terminal posts AO for phase A and terminal posts B C for phase B. The panel links are connected A^1O and CB^1. The third link is left **open.**

For a single phase connection use terminal posts AB and a panel link on posts A^1B. For three single phase connections one wire of each phase is connected to the input terminals A, B and C and the other side of each phase to the panel front terminals A^1, B^1, and C^1. That is, the connections for each of the three single phases are AA^1, BB^1 and CC^1, respectively, and all the primary links are opened.

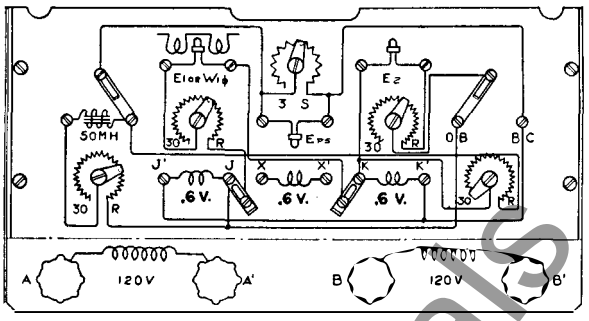


FIG. 48—SCHEMATIC WIRING OF THE HALF-LENGTH POTENTIAL CONTROL PANEL.

Each of the three potential transformers has two secondary windings to supply the galvanometers with a voltage of one two-hundredth (1/200) of the primary input voltage. The secondaries of the transformers are divided into two groups of three and are brought out to the panel front on either side, being similar in position to the primary screw-link terminals. The link can be connected in various positions to obtain many voltage combinations. The right-hand group of secondary winding is lettered XX^1, YY^1, and ZZ^1. The three secondaries are each connected to a 100 ohm enclosed variable resistance and brought to terminals PM, NU, and QY^1 respectively, to connect the galvanometer leads. The external leads can be traced to the galvanometers by the various lead colors. The left-hand group of secondary windings is lettered JO^1, KO^1, and LO^1. This winding group is connected permanently in a star connection with the center connection brought out to terminal O^1. This terminal O^1 is also connected to the center terminal of the right-hand group and to an external thumb terminal O^1. The principal function of this set of windings is to supply voltage to the positive or negative phase-sequence network for voltage indication on one galvanometer beam. Resistors F and R along with the 50 millihenry reactor coil, form the voltage phase-sequence network. To balance the network, on negative sequence A, B, C lines are connected to input posts A, B, C in the order written. With the input voltages absolutely balanced, the resistors F and R are adjusted to give zero deflection on the galvanometer connected across posts OS. The 3 ohm resistor 3S is connected across terminals O and S which is in parallel with the galvanometer element to control the beam deflection after balancing the network. The resistor 3S is put in open position or in maximum beam deflection position during the balancing of the network.

Thus, either group of secondaries can be used so as to control voltage for both wattage or voltage indications. Figs. 46 and 47 show some examples of these indications.

By arranging the flexible link connections the primaries as well as one of the secondaries of each of the transformers may be connected in any combination of star and delta. The other secondaries of the three transformers are permanently connected in star. It is evident from the above two wiring diagrams that there are many possible connections for galvanometers.

Half-Length Potential Control Panel, S # 569046

Description

The "Half-Length Potential Control Panel" is especially designed for use with the "Automatic Oscillograph". It occupies one-half the length on one side of the oscillograph as shown in Fig. 4. The panel contains two single-phase potential transformers which reduces the voltages from 120 to 0.6 volts over a frequency range of from 25 to 60 cycles per second. A schematic wiring of this panel is shown in Fig. 48. The primaries of the transformer are connected across terminals AA^1 and BB^1. Each transformer has two secondaries. The secondaries to the primary winding AA^1 are XX^1 and JJ^1. For the primary winding of other transformer BB^1, it is KK^1 and the other, not shown, is left open. There are also five variable resistors and a reactor. The two lower resistors (engraved P.S.) on the extreme ends of the panel and the reactor form the voltage phase-sequence network. The resistor 3S at the top center of the panel is connected in parallel with the phase-sequence voltage galvanometer to control its deflection. And the middle resistors are connected in series with terminals E_1 and E_2 for voltage control to two galvanometers indicating voltage.

Application and Operation

This panel is used to control the voltage to the galvanometers especially from a three-phase system connected either open delta or vee. However, it may be applied on a single-phase or a two-phase system. The control may be for voltage ndication, voltage to a single-phase watt or the two-coil three-phase watt element, a positive or a negative phase-

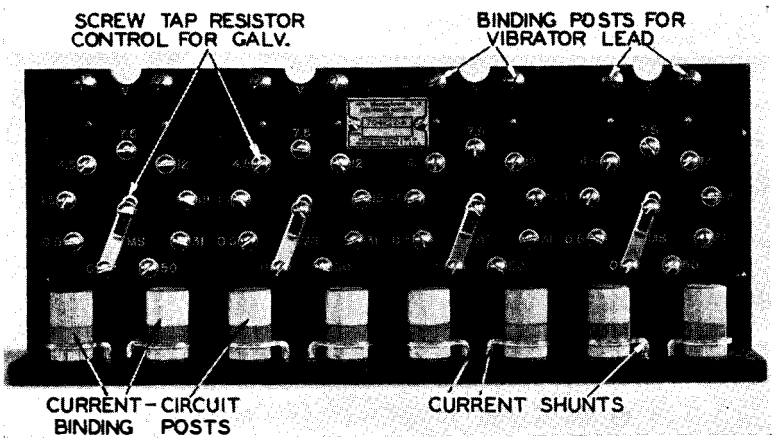


FIG. 49—FRONT PANEL VIEW OF THE HALF-LENGTH CURRENT CONTROL PANEL, STYLE NO. 704222.

sequence voltage, or it may be all three as shown in Fig. 48.

The one leg of the voltage sequence-network consists of the 50 millihenry reactor and the lower left resistor and the other leg of the network consists of the lower-right resistor. The standard panel is balanced for a sine wave 60 cycle voltage. For any other frequency rebalancing is necessary.

The network is balanced similarly to the one in the Full-Length Potential Panel. The line voltages are connected to the panel to give negative-sequence rotation. (Negative-sequence is determined by reversing the direction of current flow through transformer AA¹ and choosing the connection for the smallest deflection on galvanometer E_{ps}). It is necessary that the input voltages be absolutely equal in magnitude. With the resistor 3S in the open-circuit position, adjust the two P.S. resistors, first one then the other several times until the minimum deflection on the galvanometer is obtained. When balanced, all the fundamental frequency is removed, leaving only harmonic frequencies and disturbances. Any unbalance of the input voltage will now be indicated by a pronounced negative-sequence voltage deflection on the galvanometer. The deflection of the galvanometer must be controlled by adjusting the resistance of resistor 3S.

It may be noted from the schematic wiring, Fig. 48, that the link arrangement is made to give the same voltage on both sets of terminals E_1 and E_2. This voltage is across two legs of a star connection which is $\sqrt{3}$ times the secondary voltage of one transformer. The diagram shows the voltage connection for a single-phase watt across E_1 and a voltage connection to a permanent magnetic element across E_2. Phase or line voltage indications are obtained by connecting: for A voltage on E_1, place the middle links of the panel to XX¹. And for B voltage on E_2 change link from screw post OB to BC.

Half-Length Current Control Panel, S # 704222

Description

This panel, shown in Fig. 49, consists of four 5-ampere current shunts to each one of which is connected a 50 ohm resistance unit tapped in convenient steps to control the beam deflection of the galvanometer. The nine point screw link tap provides a positive connection for fixed calibration.

The shunts of this panel are good for 5 amperes continuously and will withstand ten times this current for a period of one minute. The shunt resistance is 0.05 and they have a drop of 250 millivolts at their rating of 5 amperes.

The panel fits into the oscillograph beneath the galvanometer compartment shown in Fig. 4 and the wiring diagram is shown in Fig. 49-A.

Application

The panel is designed to give galvanometer control of four independent current circuits (three line currents and one neutral current.)

Operation

The current leads or leads from current transformers may be connected to the binding posts in the base of the panel. The leads to the vibrators are taken from the small binding posts at the top of the front panel. The galvanometers to which the leads go can be determined by the colored leads supplied with the oscillograph case.

The Half-Length Angle Indicator Control Panel, S # 584394

Description

This panel, wiring Fig. 50, consists of three units, two potential units which are identical, and one current. The potential units consists of a potential transformer which supplies the vibrator through a 50 M.H. inductance and a 30 ohm variable resistance in series. There is also a variable resistance of low value connected in parallel with the vibrator which is used to control the response of the vibrator and also to protect it against excessive currents. The current unit also has a step down transformer the secondary of which has a center tap. It is designed to furnish a current of from 3 to 4 amperes to the current coils of watt galvanometers. Using half the secondary winding, it will supply one coil, and, using the entire winding, it will supply two coils in series. There is also a series resistance for the purpose of controlling the magnitude of the current.

Application

This panel is usually used in conjunction with one or two "Single Phase Watt Galvanometers" for the purpose of indicating angle and changes of angles between a current and a voltage or two

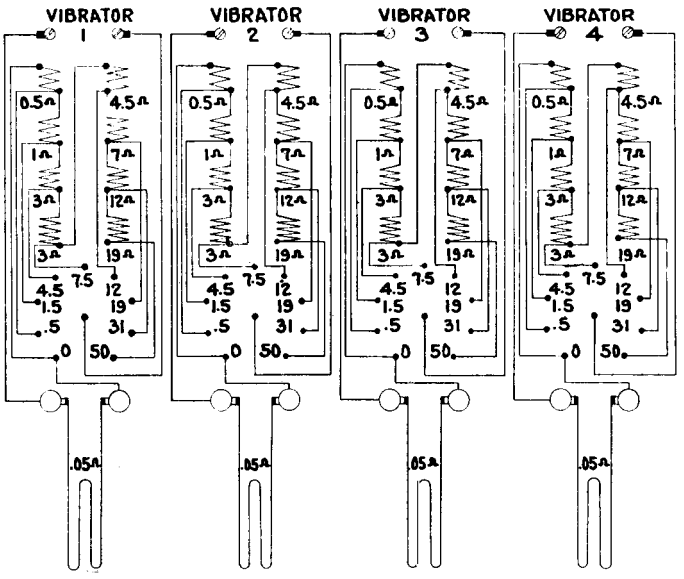


FIG. 49-A—INTERNAL WIRING OF THE HALF-LENGTH CURRENT CONTROL PANEL.

voltages. From this it can be seen that it has numerous applications for indicating power factor, changes in angles due to load unbalance, changes of angle during switching operations, etc. With the use of pilot wires it can be used to indicate the shift of angle at distant points along a transmission line.

Operation

1. **Angle between Two Voltages:** In this case one potential is connected to the center pair of binding posts and the other potential to either outside pair of posts. The current coil of the Watt Galvanometer is connected between the studs marked "Coil 3-4A" and the voltage coil between the stud marked "Vibrator" to correspond to the posts to which the primary potential is applied. At the bottom of the front panel the outside links are connected to the studs marked "L" and the center link to the stud marked "1".

With the power on, adjust the rheostat marked "30-R" until the galvanometer gives zero displacement, that is, until the galvanometer beam oscillates symmetrically about its mechanical zero. This gives an angle of 90° between the currents in the voltage and current elements of the galvanometer, See Fig. 51. At the same time adjust the rheostat marked "Vibrator" so that the amplitude of vibration is not excessive. The amplitude can also be varied using the rheostat marked "¾-R".

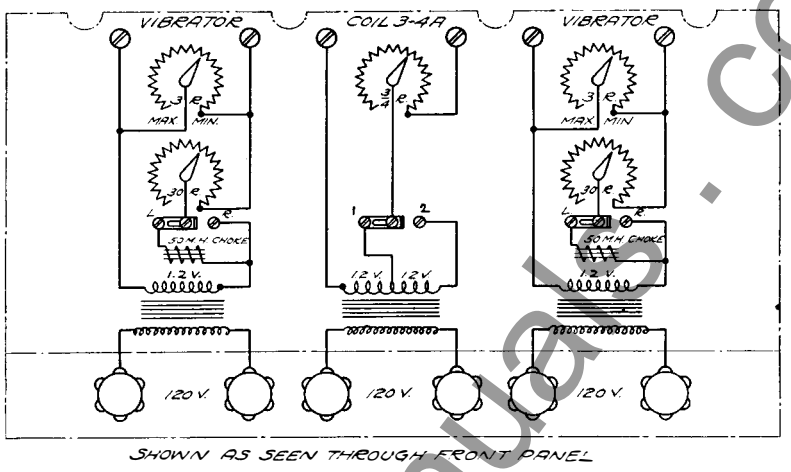


FIG. 50—INTERNAL WIRING DIAGRAM OF THE "HALF-LENGTH ANGLE INDICATOR CONTROL PANEL".

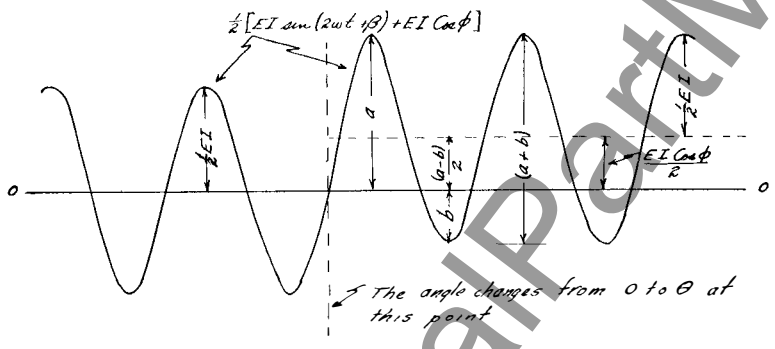


Fig. I
Record Given By Instantaneous Watt-Galvanometer.

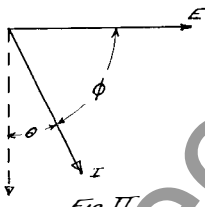


Fig. II
Vector Diagram of Watt-Galvanometer.

E = Voltage in galv. potential element.
I = Current " " current " "
Θ = Angle of displacement
Cosφ = Power factor of galv.
β = Any constant angle
ω = Angular velocity
t = Time
a = Distance to one peak.
b = Distance to other peak

From $\frac{1}{2}[EI\sin(2\omega t+\beta)+EI\cos\phi]$, it is seen that EI is the amplitude of the wave measured from the center line or axis of the wave.

$$\therefore \tfrac{1}{2}EI = \frac{a+b}{2}$$

$\therefore$ The displacement of the center line is

$$\frac{a+b}{2}\cos\phi$$

But the displacement of the center line also is

$$\frac{a-b}{2}$$

$$\therefore \frac{a+b}{2}\cos\phi = \frac{a-b}{2} \qquad \therefore \cos\phi = \frac{a-b}{a+b} \quad \text{and} \quad \sin\theta = \frac{a-b}{a+b}$$

FIG. 51—MATHEMATICAL DEVELOPMENT OF THE DISPLACEMENT ANGLE BETWEEN THE TWO OR MORE ELECTRICAL QUANTITIES BEING STUDIED.

The resistor "30-R" will give a change in angle of greater than 30° depending on the frequency of the source. By using different combinations of star and delta transformer connections, the 90° relation mentioned above can easily be obtained.

As the angle now changes from the one at which the panel is set, it can be seen that the 90° relation within the galvanometer is destroyed and the galvanometer beam will be displaced from the zero position, that is, it will indicate power. This power is proportional to the sine of the angle of displacement. If the deflection is in one direction, it indicates the angle is larger, if in the other, it indicates the angle is smaller.

When a fin type galvanometer is used, the record is a line, that is, it is not a wave. The displacement of this line from the zero position is proportional to the sine of the displaced angle. In order to read angles directly using this type galvanometer, it is necessary that the combination be calibrated.

When an instantaneous type galvanometer is used the record is a wave of double frequency. The displacement of the center line, or axis, of this wave is again, as above, proportional to the sine of the angle. However, the angle can be determined in another manner which is independent of the amplitude of vibration or amount of displacement and hence no calibration is required. If the distance from the zero line to one peak is "a" and to the other peak is "b", then,

$$\text{Sine } \Theta = \frac{a-b}{a+b}$$

where Θ is the angle of change between the two voltages, as developed in Fig. 51.

If it is desired to determine the changes of each angle between two voltages with respect to another, (knowing two angles between two voltages to a three phase system, the third angle of

PANEL BURDENS

Panel	Panel Part	Approx. Burden (Volt-Amps.)
Automatic Panel	A-C. Relays 1 Amp.	Open .42 Closed .67 @ 1A.
	5 Amp.	.39 .50 @ 5A.
Lamp and Motor Supply Panel	Transformer: Open Cir.	3.6 VA @120 V. 60 Cyc.
	Full Load	75.0 VA loaded continuous
Half or Full Length Pot. Panels	Each Trans.: Open Cir.	0.28 VA @120 V. 60 Cyc.
	Loaded	See Galvanometer Burdens
Network Panel for Initiation	Circuit Bur.: 60 C. Panel	Negative Seq. Conn.: 6¼VA@5A. Bal. Ld. per leg 12½ Total.
	50 C. Panel	5¼ VA @ 5A. Bal. Ld.

Fig. 51-A—Volt-Ampere Burdens for Control Panels.

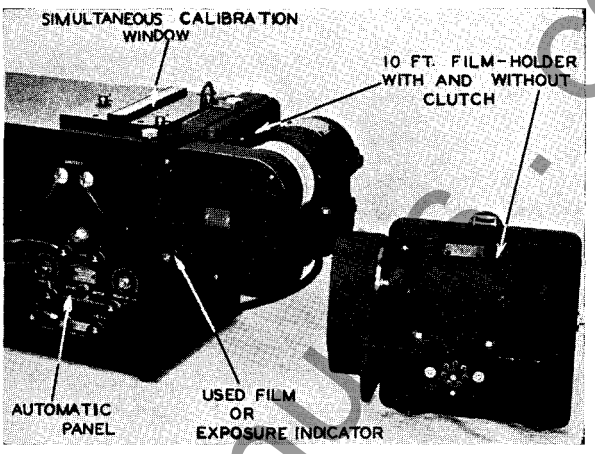


Fig. 52—Filmholders for 5 or 10 Feet of Film or Sensitized-Paper—One with the Magnetic Clutch Mounted on the Automatic Oscillograph and the Other Shown Unmounted without Magnetic Clutch.

course is evident) the third potential is connected to the remaining potential unit. A second galvanometer is connected as explained before with its current coil in series with the current coil of the first galvanometer. The center link on the panel must then be changed to position "2". The unit is then balanced and operated as before.

2. **Angle Between a Current and a Voltage (Power Factor):** In this case the potential is connected to either outside pair of binding posts and current, if it does not exceed 5 amperes, is connected directly to the studs marked "Coil 3-4A". If the current exceeds 5 amperes suitable shunts or current transformers must be arranged. The outside links are connected as before, but the center link is left open.

With the power on, and a unity power factor load, the rheostat "30-R" is again adjusted until the galvanometer gives zero displacement. This again gives the 90° relation between the currents in the galvanometer.

As the power factor now changes from unity, the 90° relation is destroyed and the galvanometer beam will be displaced proportionally to the sine of the power factor angle. The angle can be determined from the records as before.

The change in angle between two voltages with respect to a current can also be determined. In this case the second potential is connected to the remaining potential unit. A second galvanometer is connected as before with its current coil connected in series with the current coil of the first galvanometer. The unit is then balanced at unity power factor after which it is ready for operation.

It is not necessary to balance the panel at unity power factor if only a record of the change in power factor is wanted. In this case the panel is balanced at the normal power factor of the line on which it is to be used. Then, in operation, it will give the variation from the normal power factor.

PHOTOGRAPHIC ATTACHMENTS

Filmholder for 10 Feet of Sensitized Paper or Film

Description

Several views of this filmholder are shown in Figs. 52 and 53. This filmholder, which is daylight loading, was designed primarily to be used with the "PA" line of oscillograph to use sensitized-paper or film 5 inches wide and in lengths up to 10 feet. A used film indicator is built into the holder. The film indicator gives the exposed film to the nearest 5 inches, that is, the indicator moves up every 5 inches or once for every revolution of the main drum. This film indicator dial may be set to zero by pressing the finger on the rim of the dial wheel and turning it.

The filmholder is driven by an integrally mounted motor either direct-drive or through a magnetic clutch. This motor is mounted on a bracket and gear assembly which in turn is mounted on the camera housing and held secure, screwed, at three points. With this motor, bracket and gear assembly removed, the camera housing assembly can be used by driving the main drum with an externally mounted motor through a belt and pulley. The integrally mounted motor is of two types, one the wide-range, adjustable speed, Lee governor type for use on 120 volts a-c.—d-c. or 6 volt battery supply. The other is the regular 6-volt d-c. shunt motor. The speed of the governor motor is controlled by turning the thumb knob opposite the drive end of the motor. The shunt motor has its speed adjusted by changing the field or armature voltage by a rheostat or by changing the field or armature leads at the battery terminals, see table Fig. 52-A.

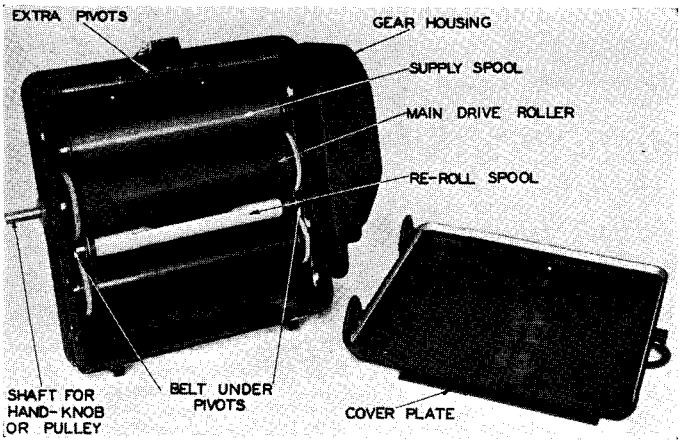


Fig. 53—Filmholder for 5 or 10 Feet of Film or Sensitized-Paper, Showing the Cover or Mounting Plate and a View of the Rollers and Inserted Spools for Proper Loading.

10 FT. FILMHOLDER FILMSPEEDS FOR VARIOUS BATTERY CONNECTIONS WITH 6 VOLT SHUNT MOTOR

Approx. Film Speeds*	Armature Volts**	Motor Fld. Volts**
¼ ft./sec.	2.2	6.6
⅔ ft./sec.	4.4	6.6
1 ft./sec.	6.6	6.6
1¼ ft./sec.	6.6	4.4‡
1½ ft./sec.	8.8	6.6
2 ft./sec.	11.0	6.6

*Filmspeeds are for the low-gear ratio—the high ratio will give ½ the above values.
**Voltages are 10% higher than the regular battery taps.
‡A charger is recommended to hold the voltage to 6.6 volts, which value is required with the automatic panel; therefore, a motor-field rheostat must be used to obtain the 4.4 volts.

Fig. 52-A—Battery Connections to Give the Approximate Filmspeeds with the 6 Volt Shunt Motor Used for Automatic Operation. For Different Speeds between the Given Points, a Motor-Field Rheostat Must Be Used.

SENSITIZED PAPER AND FILM FOR 10 FT. HOLDER

Length	Film Style‡ 5 In. Wide	Paper Style‡ 5 In. Wide
2½ ft.	930648	.....
5 ft.	921899	721347
10 ft.	682184	721348
15 ft.*	819650	.....

*Dark room loading.
‡Empty spool S #819660.

Fig. 52-B — The Above Table Shows the Recommended Styles of Sensitized-Paper and Film for the 10 Ft. Holder.

Application and Operation

The regular shunt motor with or without the magnetic clutch is generally used for automatic power application. With the battery voltage (which is approximately 6.6 volts when backed by charger) applied to both the field and armature the motor speed and gear ratio are such as to give approximately one foot per second of the recording paper.

10 FT. FILMHOLDER FILMSPEEDS USING THE GOVERNOR TYPE MOTORS

Approx. Film Speeds*	Motor Voltage	Motor Style	**Governor Setting
½ ft./sec.	6.6 V. D-C.‡	877070	Min.
2½ ft./sec.	6.6 V. D-C.‡	877070	9/10 Full
½ ft./sec.	115 V. A-C.	877069	Min.
2½ ft./sec.	115 V. A-C.	877069	9/10 Full

*Film speeds are for the low gear ratio—the high ratio will give ½ the above values.
**The governor may be set for any value between the full and minimum settings.
‡This value may be increased to 10 volts for short intervals to obtain higher torque outputs.

Fig. 53-A—Maximum and Minimum Filmspeeds Recommended when Using the Lee-Type Governor Motors.

This speed may be reduced to half or one-half foot per second by turning the gear, which is driven by the motor pinion, upside down, and remounting it to give a larger speed reduction. This gear is removed by unscrewing the bearing shaft and turning it counter-clockwise, or the speeds may be doubled by putting 6.6 volts on the field and 11.0 volts on the armature, see table Fig. 52-A. Any film-speeds between the various battery taps are obtainable by a motor field rheostat such as supplied in the automatic panel.

With this motor on the filmholder one of the major applications is in the field of automatic recording of faults, particularly in the field of power transmission system analysis where the oscillograph is left unattended for long periods. With the use of the magnetic clutch the starting time is that of the closing of the magnetic clutch, which runs from 1/10 to 1/6 of a 60 cycle wave (0.0028 to .0015 seconds) depending on the gap setting of the clutch.

A wide application of this filmholder has been found in the laboratory and industrial field. For this purpose, the adjustable speed governor motors are used, without the magnetic clutch. Film speeds from approximately one quarter foot per second up to 2½ feet per second are obtainable using this type of integrally mounted motor, see Fig. 53-A.

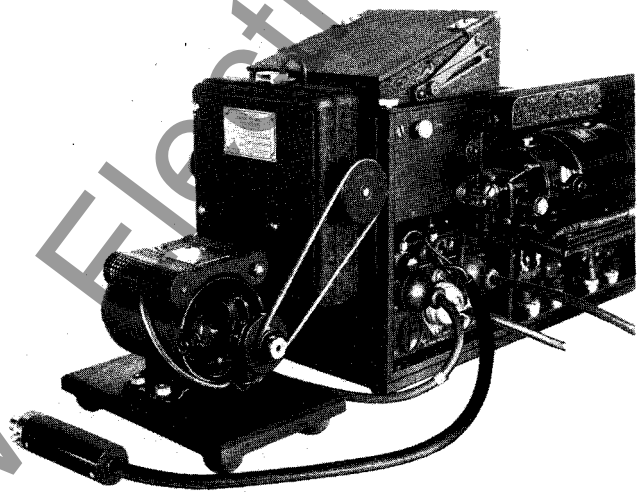


Fig. 53-B—Filmholder for 5 or 10 Feet of Film or Sensitized Paper with Belt and Pulley Drive for Higher Film Speeds.

Where it is desirable to use higher film speeds than those obtained with the integrally mounted motor, a belt and pulley drive may be used as shown in Fig. 53-B. Film speeds up to 15 feet per second may be obtained, which represents the maximum safe speed at which the filmholder may be used. The integrally mounted motor and gear housing are removed from the filmholder, and a pulley is attached to the main drum shaft. A governor type motor is supplied with three stepped pulleys to drive the drum filmholder. Changes in pulley ratio are obtained at the motor pulleys, and the belt is kept taut by moving the motor and pulley unit as necessary. The governor motor has a speed range from approximately one-fifth speed to full speed. The table in Fig. 53-C shows the range of speeds that may be obtained with each pulley ratio.

Where it is desirable to use pulley drive and have low film speeds another pulley attachment S #492505 may be obtained.

10 FT. FILMHOLDER FILMSPEEDS USING THE GOVERNOR TYPE MOTOR AND PULLEY WITH BELT DRIVE

Approx. Film Speeds	Pulley Ratio
1.5 ft./sec.— 7 ft./sec.	Low
3.0 ft./sec.—15 ft./sec.	Medium
6.0 ft./sec.—30 ft./sec.*	High

*Maximum safe speed is 15 ft./sec.

Fig. 53-C

Loading the Film

To load or reload the film in the 10 foot holder, the cover may be left on the oscillograph.

1. Start by releasing the spring clip at the top of the holder and remove the holder from the oscillograph by leaving the cover plate on the front panel of the oscillograph.
2. Insert a spindle or pivot (6 supplied) in each end of the new film spool.
3. Break the seal on the new film spool and unroll about three inches.
4. Remove the empty spool S #819-660 and place the new spool in the slots at the top of the holder and press the spool flanges against the retarding springs until the pivots slide down the lateral

200 FT. FILMHOLDER FILMSPEEDS FOR VARIOUS BATTERY CONNECTIONS WITH MOTOR STYLE NO. 773274

Approx. Film Speeds	Armature Volts*	Motor Fld. Volts*‡
1/6 ft./sec.	2.2	6.6
3/4 ft./sec.	4.4	6.6
1 1/4 ft./sec.	6.6	6.6
2.0 ft./sec.	8.8	6.6

*Voltages are 10% higher than the regular battery taps.
‡A charger is recommended to hold the voltage to 6.6 volts, which value is required with the automatic panel. Intermediate speeds may be obtained with the field rheostat of the automatic operating panel.

Fig. 55-A—Battery Connections to Give the Approximate Filmspeeds with the 6 Volt Shunt Motor Style No. 773274 Used for Automatic Operation

200 FT. FILMHOLDER FILMSPEEDS USING THE GOVERNOR TYPE MOTORS

Approx. Film Speeds*	Motor Voltage	Motor Style	Governor Setting**
1/2 ft./sec.	6.6 V. D-C.‡	877 070	Min.
2.0 ft./sec.*	6.6 V. D-C.‡	877 070	3/4 Full
1/2 ft./sec.	115 V. A-C.	877 069	Min.
2.0 ft./sec.*	115 V. A-C.	877 069	3/8 Full

Gearing for speed range 1"/sec. to 5"/sec. furnished on request.
*Speeds in excess of this value are not recommended.
**The governor may be set for any value between the full and minimum settings.
‡This value may be increased to 10 volts for short intervals to obtain higher torque outputs.

Fig. 55-B—Maximum and Minimum Filmspeeds Recommended when Using the Lee-Type Governor Motors.

grooves to bring the fullness of the spool to lie against the main rubber driving rolls, in such a position so that the leader comes out between the driving roll and the film spool.

5. Take the empty spool previously taken out with the pivots still in and introduce the leader into the wide side of the slot in the wood core.

6. Wind one turn of the leader around the empty spool in a direction to leave the red side out.

7. Place this reroll spool in the slots below the main rubber drive roll so that it is clamped between the two lower drive rolls, being sure that the rubber belts are underneath and drive on the pivots of the reroll. (See Fig. 53). Loaded thus, the black side of the leader will show over the top of the main drum drive.

8. Place the holder back on the cover plate and clamp the spring-clip.

9. By the hand knob on the main drum shaft give the main drum 2 1/2 turns for commercial ("Kodak" #104) film and 3 turns for the Westinghouse film to advance the film to the writing plane.

10. Set the used film indicator on zero and the holder is ready for use.

Filmholder for 200 Feet of Sensitized Paper or Film

Description

This filmholder, shown in Figs. 54, 55, and 56, is daylight loading and was designed for use with the "PA" line of oscillographs. It takes either sensitized paper or film 5 inches wide and any length up to 200 feet, see Fig. 55-C. It is so arranged to expose any length of either paper or film up to and including the full 200 feet. The exposed paper is fed into a separate lower magazine where at any time it may be cut off and removed for development without disturbing the unexposed portion. The holder is equipped with an exposure indicator to indicate the length of paper or film used. The indicator measures the film length to the nearest foot. Also, an extra lower magazine is supplied, which enables the oscillograph operator to continue taking records while the other magazine is sent to the dark room for development of the previous record.

SENSITIZED PAPER AND FILM FOR 200 FT. HOLDER

Length	Film Style‡ 5 In. Wide	Paper Style‡ 5 In. Wide
200 ft.	821691	821694

‡Empty spool S #820870.

Fig. 56-C—The Above Table Shows the Recommended Styles of Sensitized-Paper and Film for the 200 Foot Holder.

An automatic **OPERATION INDICATOR,** shown in Fig. 54, may be obtained which will automatically total up the number of exposures on the film. This attachment is particularly useful in automatic power application where it provides the number of operations or fault recordings during any time interval. The automatic operation indicator, when used in conjunction with the automatic operation panel S #877042, has one terminal tied to ground (minus 6 volts) through the frame of the film holder. The other terminal is connected to the second external initiating terminal of the automatic operation panel as shown in Fig. 41.

Automatic operation indicators for Laboratory applications may be obtained for either 115 volts A-C. or 6 volts D-C. These indicators are used with the film holder in conjunction with the Lamp Control Panel S #877043, see Fig. 36.

The operation indicator is plugged into the proper outlet A-C or D-C receptacle Fig. 36, depending upon the

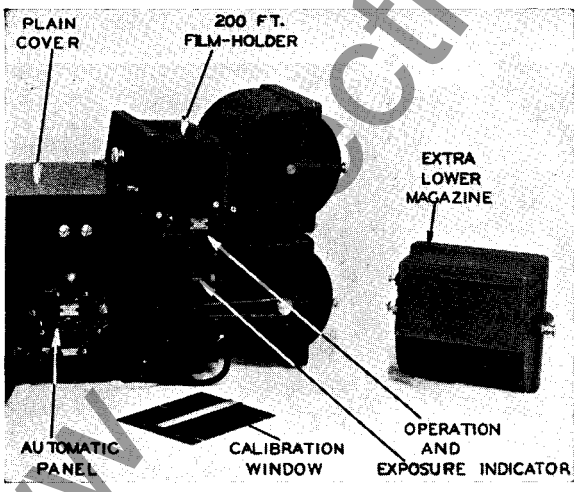


Fig. 54—Filmholder for 200 Feet of Paper or Film Shown Mounted on a PA Automatic Oscillograph.

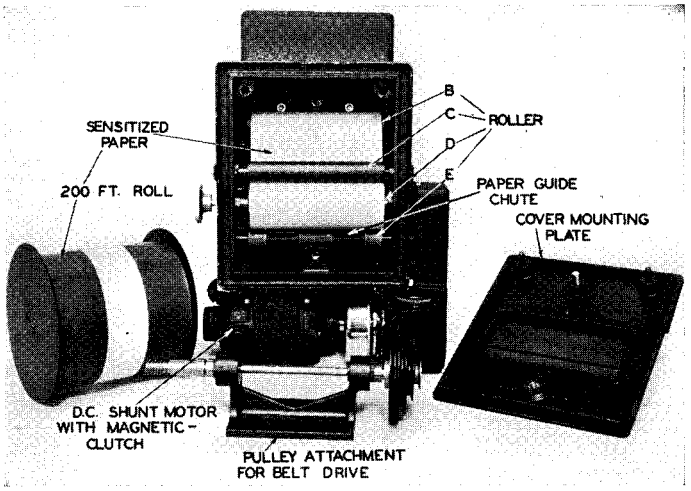


Fig. 55—Rear View of Filmholder for 200 Feet of Paper or Film with Mounting Cover Removed Showing the Internal Rollers.

source of supply. The indicator will register each time an exposure of the film is made.

The filmholder is driven by either an integrally mounted motor direct worm drive or by a separately obtained pulley drive in which case the filmholder is driven by an externally mounted motor. The integrally mounted motor may be of the wide adjustable speed range Lee governor controlled motor for either 120 volts ac.—dc. or 6 volt battery supply, or the regular 6 volt ac. shunt motor which has its speed adjusted by a motor field rheostat, or by varying the voltage by means of battery taps, see Fig. 55-A. When applied to automatic operating, the rheostat in that panel may be used.

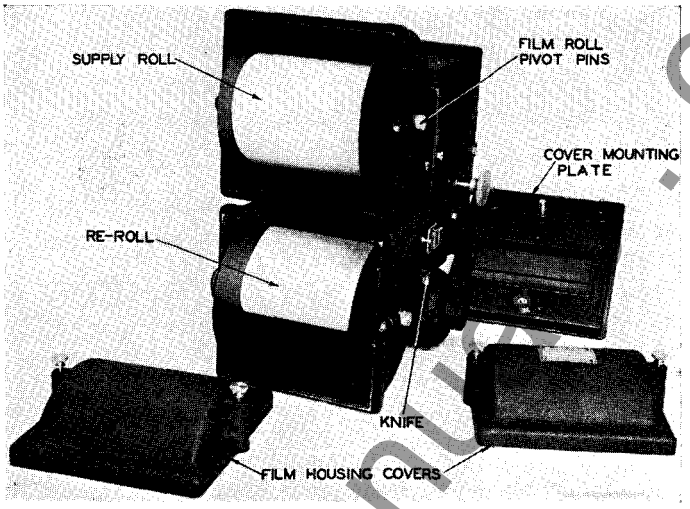


FIG. 56—FRONT VIEW OF FILMHOLDER FOR 200 FEET OF PAPER OF FILM WITH MAGAZINE COVERS REMOVED SHOWING THE SUPPLY AND REROLL SPOOLS.

Application and Operation

The regular shunt motor, with or without the magnetic clutch, is generally used for automatic applications. With 6.6 volts applied to both the field and armature, the motor speed and gear ratios are such as to give approximately one and a quarter feet per second of the recording surface. One of its major applications is in the field of automatic fault recording, particularly in the field of power system analysis where the oscillograph is left unattended for long periods. With the use of the magnetic clutch, the starting time of the recording paper is not more than ¼ of a 60 cycle wave, or a time of approximately 0.004 of a second. The starting is within a ¼ of a 60 cycle wave and the recording paper is up to a uniform speed within the first cycle after starting. This quick starting is obtained by means of a floating or an oscillating arm which holds a loop of film that can be readily accelerated while the rest of the film roll is being brought up to speed. This quick starting loop is accelerated into action by the magnetic clutch revolving on the continuous running motor shaft. This motor and clutch is shown assembled on the filmholder, Fig. 55. As this motor runs or idles at practically no load, other than the friction losses, its life is of the order of several years of continuous running.

A wide field is also found in the experimental laboratory where long and comparatively slow film speeds are required. Usually for this purpose the adjustable speed governor motors are used without the magnetic clutch. Film speeds from .3 to 2.0 feet per second can be obtained, see Fig. 55-B. A pulley and belt drive from an external motor shown in Fig. 55 can be obtained as a separate drive. The filmholder can be successfully used for film speeds from less than one inch to twenty-four inches per second, see Fig. 55-A. When using the pulley and belt drive, several oscillographs can be run in parallel and the several filmholders can be connected tandem mechanically through a common coupling shaft driven by one motor and the one belt, see Fig. 57-A. This insures a uniform speed for all records. In such a set-up the light sources for all the oscillographs are connected to the same source or control. One element in each oscillograph should be connected to record the same phenomena so as to tie the records together.

A list of the film and paper used is shown in Fig. 55-C.

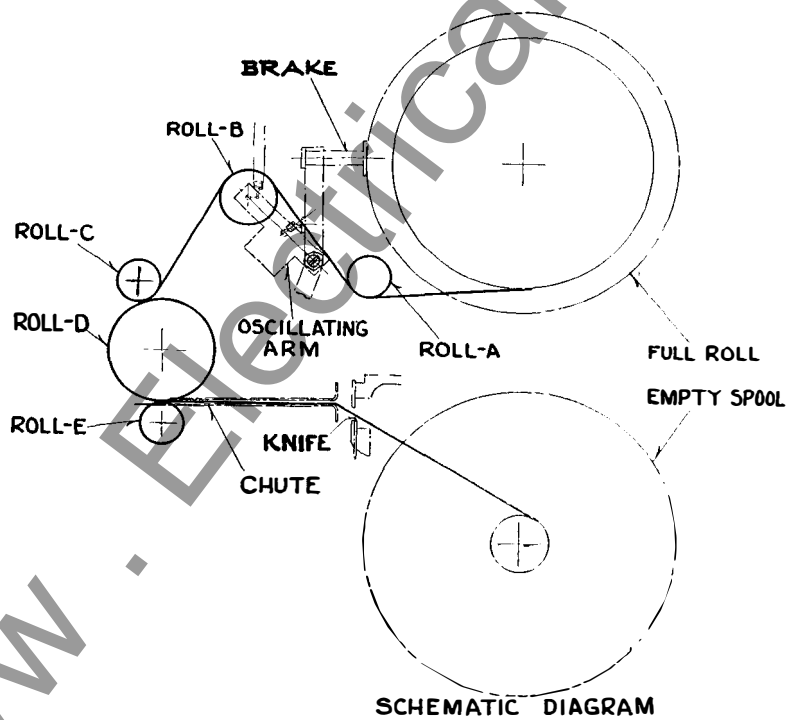


FIG. 57—SCHEMATIC DIAGRAM OF THE FILMHOLDER FOR PAPER OR FILM IN LENGTHS UP TO 200 FEET.

Loading Instructions for 200 Ft. Filmholder

When following the instructions for loading this filmholder, the side with the gear housing and spring belt will be known as the left side. The part that fits on to the oscillograph will be known as the back. (See Figs. 54, 55, 56, 57 for reference.)

To load with a new roll of paper, the following procedure is recommended:

1. Dismount the complete filmholder from the oscillograph.
2. Take mounting plate off by removing the two knurled thumb screws.
3. Remove two covers on front by unscrewing the four knurled thumb screws.
4. Pull the bearing pivots out to the stop position on both upper and lower magazine.
5. Break the seal on the film roll and unwind about 8 inches of the red and black leader. Push the leader through the slot and under roll A, Fig

57, being sure the black side of leader is against the roll. Insert roll into magazine, and push the bearing pivots into the holes in the center of the roll.

6. Replace cover on magazine.

7. Turn the holder around so that you face mounting side and put the paper leader over roll B, as shown in Diagram, between rolls C and D and between rolls D and E. Same care should be taken to have the paper straight before putting it between rolls D and E, which will drive it into the chute. Be sure the knife handle on the right side of the lower magazine is in the up position. Attach the extension plug and press the film motor switch button momentarily or long enough to get the end of the paper leader into the receiving magazine. Reach into the lower or receiving magazine and pull the paper through about six inches, making sure the paper is tight on the rubber roll D.

8. Replace the back plate.

9. Insert the empty spool in the same manner as the full roll of film, except that the pin in drive bearing pivot goes into the slot in one end of the empty spool.

10. Clamp the end of leader with C spring clamp and wind on about two turns. Be sure that the rotation is top coming. In other words, the black side of the leader should be against the wood core of the spool.

11. Replace magazine cover.

12. Advance enough film so that the sensitized paper may be seen through the slot in the back plate.

13. Put filmholder in position on oscillograph.

14. Set counter which measures feet exposed, to 000.

15. Advance paper about 3 inches, and the holder is ready for operation.

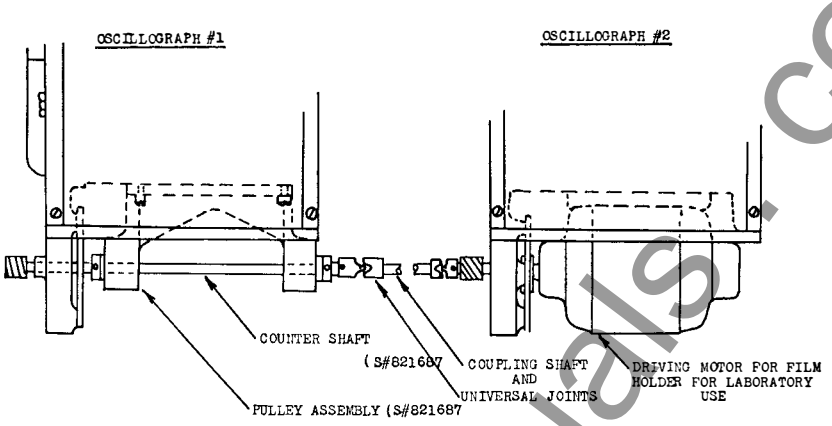


FIG. 57-A—CONNECTING FILM HOLDERS IN TANDEM.

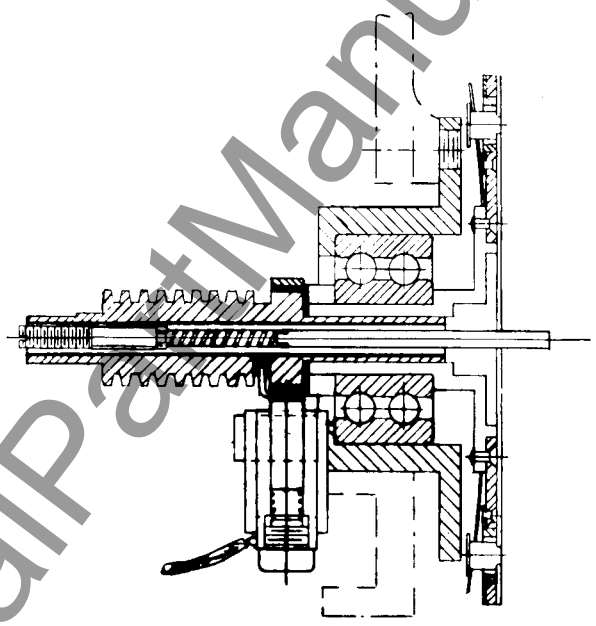


FIG. 58-A—MAGNETIC CLUTCH FOR TANDEM OPERATION.

Removing Exposed Section of Film and Reloading Empty Spool

1. Press down knife handle on right side of lower magazine. This handle should be left down as it forms the shutter to the lower magazine.

2. Remove spring belt from pulley on magazine.

3. To remove magazine, release spring clasp on right side and pull the right side of the magazine forward about one-half inch, and move to the right.

4. Take to dark room before removing film from magazine.

5. Replace empty magazine.

6. Put knife lever in up position.

7. Press button on automatic operation panel to advance six inches of film.

8. Trim film to point and insert in reroll spool.

9. Place film in wood spool and wind two turns tightly. Be sure that rotation is top coming. In other words, the sensitized part of the paper should be towards the wood spool.

10. Replace the cover.

11. Replace the belt so that rotation is top coming.

12. Holder is now ready for operation.

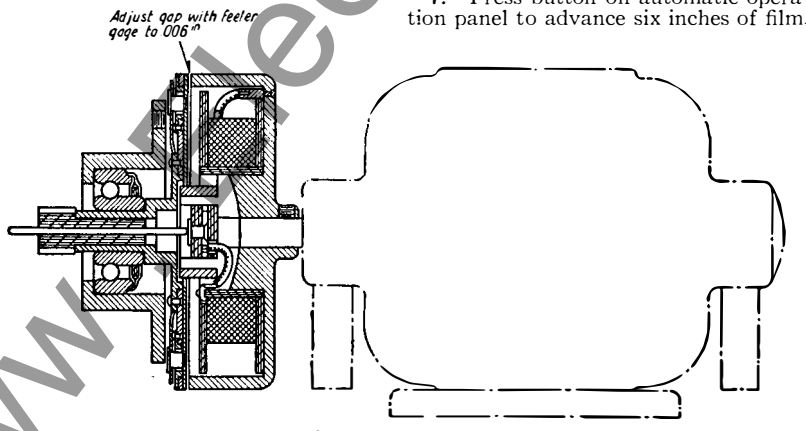


FIG. 58—MAGNETIC CLUTCH OUTLINE.

MAGNETIC CLUTCH

For 10 Ft. and 200 Ft. Filmholders

Description

The magnetic clutch, for operating a single oscillograph, is shown in Fig. 58 and is designed for automatic operation on low voltage dc. The coil and housing unit are mounted on the motor shaft and revolve with it. The clutch disc and pinion unit are mounted by means of three screws on the gear case. Contact to the low resistance clutch coil is made by inserting the contact pin through the driving pinion. A flat leaf pressure

spring holds this contact pin firmly against the contact center of the coil and housing. The other side of the clutch coil is grounded and the connection is made at one of the motor mounting screws. The clutch coil is connected in series with the adjacent filament of the same lamp as used by the shutter and hence across a 6 to 8 volt battery. (See automatic panel wiring diagram. Fig. 43).

The magnetic clutch which is used when two oscillographs are operated in tandem is shown in Fig. 58-A. It differs from the clutch for single oscillograph operation in the manner of making contact to the clutch coil. A motor brush is mounted on the side of the clutch in place of the flat leaf pressure spring. This permits the use of the coupling shaft and universal joints to connect the two oscillographs in parallel.

Application

When using the magnetic clutch the motor is mounted to the right to give room for the clutch, and four mounting holes are located for this mounting on both the 200 or the 10 foot filmholder brackets.

The motor is properly positioned by the clearance in the mounting screw holes and is adjusted to give a small uniform airgap (see Fig. 58), between the disc and clutch housing either equal to or slightly greater than .006 inch. The connection "motor link" (see automatic panel) is made so the motor will run continuously. It is necessary to close the clutch circuit across the battery by the push button switch on the automatic panel to load or advance the film in the holders.

The clutch gives almost an instantaneous start of the film and a uniform spread of the record throughout its length. A very nice appearing record of unusually short length can be taken by closing the switch for the time interval desired. The length of record is proportional to the length of time the switch is closed as very little time is used for the acceleration of the film.

Magnetic Shutter

Description

The magnetic shutter which is designed for automatic operation on **low voltage d-c. only** is shown in Fig. 59 and consists essentially of an oblong heavy-copper wire coil assembled in an iron frame with two long thin iron vanes which close the opening through the coil. These vanes are held closed by a wire spring. Upon energizing the shutter coil, the two vanes are drawn apart magnetically to allow the light beams from the galvanometers to pass through the coil center. When the shutter current ceases, the vanes are forced closed by the spring and shut off the passage of light to the filmholder.

Application

The shutter coil, which is of low resistance, is connected in series with one filament of a standard double filament 32 candle power automobile lamp and hence across a 6 to 8 volt battery. The object of the series lamp is to give a large current surge for snappy opening of the shutter and a low economical current after the lamp has heated up to hold the shutter open.

The shutter was purposely designed to operate with the magnetic clutch on the high-speed automatic oscillograph where the lamp is kept preheated slightly below normal. On the continuous drive film-holders for automatic operation where the initiating time is from ½ to 1 cycle it permits the examination of the start of the record by eliminating the black line of the film caused by the exposure of the preheat lamp. Where automatic operation is not required, the use of the shutter can be dispensed with.

If desired, the shutter blades are held open mechanically by pressing in the hand lever positioned at the right front corner of the oscillograph case.

The magnetic shutter is not used with the new type drum filmholder as the shutter is incorporated right in the holder. However, this type of magnetic shutter works very conveniently with the Osiso drum-type film-holder and will open and close at speeds above 30 feet per second without retrace.

Rotating Drum Film Holder 5″ x 11″ 3 21/32″ x 11″ Record

Description

The rotating drum film holder, Fig. 60, 61, 62, 63, 64, is available for operation on 115 volts AC-DC or 6 - 10 volts D-C. It is designed to use sensitized paper or film for either dark room or daylight loading as required and is used in conjunction with panel S# 877-043. For very economical operation, where dark room loading is not a disadvantage, cut-film or paper may be used. This method is particularly advantageous for school laboratories where the cost of records must be kept to a minimum. For routine laboratory work daylight loading rolls are available. Cut-film or paper may be obtained in 3 21/32″ or 5″ widths 14″ long. Roll film may be obtained in the same widths for 2, 3 and 5 exposures. The style list of photographic materials gives the items normally available.

When using dark room loading, speeds of 6 inches up to 35 feet per second may be easily obtained; with roll film this value is 25 feet per second. The speed changes are obtained by means of a variable stepped pulley and belt drive plus a variable speed governor type motor. The ranges are sufficiently close to cover practically all the requirements usually met in the laboratory.

The film holder is equipped with a film register to indicate the number of exposures. The knob that winds the film can also be used to tighten the film around the drum and lock it in place to prevent its flying away from the drum at high speeds.

On the opposite side of this mechanism is a worm traveller which is a sequence device to determine the start of phenomena to be photographed in relation to the beginning of the exposure on the drum. The device will close a switch or open a switch during the exposure or up to seven revolutions in advance of the exposure. During this sequence the lamp which is preheated is flashed to give increased light during the exposure. The

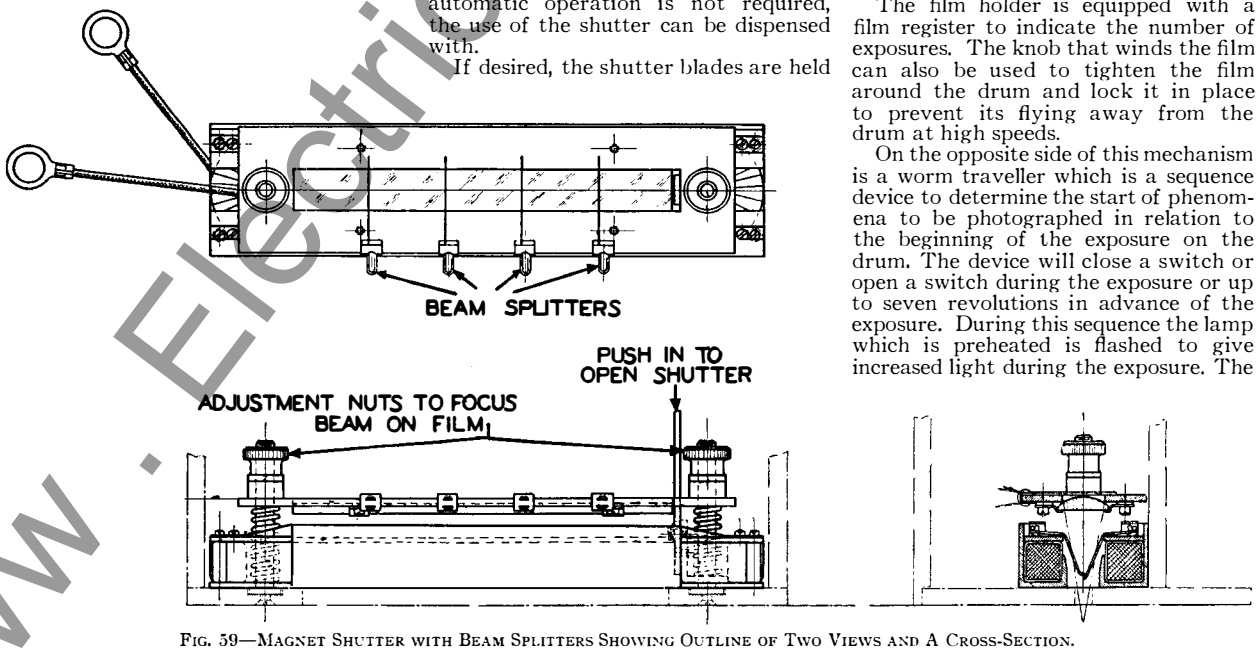


FIG. 59—MAGNET SHUTTER WITH BEAM SPLITTERS SHOWING OUTLINE OF TWO VIEWS AND A CROSS-SECTION.

closing or opening switches are rated at 10 amperes 120 volts A-C. This sequence device also trips, by means of suitable cams, the self-contained shutter which at the end of the operation sequence may be locked closed to prevent the film being light struck when the holder is removed from the front of the oscilograph.

In place of the worm tripping mechanism shown in Fig. 60 a cam tripping mechanism, Fig. 61, may be substituted. This is accomplished by removing three mounting screws which hold the mechanism to the side of the film-holder. The purpose of the cam tripping mechanism is to permit electrical conditions to initiate the exposure. In this case the exposure will start anywhere on the drum, but will take place for (1) revolution only. The result will be that the record will be in most cases, divided where the ends of the film meet on the drum. When the film-holder is used dark room loading instead of dayligt loading, the smallest possible gap in the record (approximately ¼ inch) will take place.

Application and Operation

The film-holder finds its main application in the study of non-recurring transients of short duration, such as those found in welding equipment, circuit breakers, switches, fuses, and ignition coils. It also finds a wide field of application in the studies of motor characteristics under starting and load conditions, or in the studies of non-electrical phenomena translated into electrical quantities such as pressure studies in internal combustion engines.

In operation the filmholder is mounted in the slot on the front of the oscillograph as shown in Fig. 62 The motor is connected to the proper source as indicated by the name plate rating. When used with panel S # 877043, the connection receptacles are marked as shown in Figs. 36 and 37. These figures also show a switch marked "Motor SW" and "Lamp SW". The "Motor SW" must be connected through either the hand switch cable Fig. 36 or a suitable jumper. The latter method is satisfactory when the motor cable has a switch in it. The "Lamp SW" terminals must be connected to the terminals shown in Fig. 60. Shorting of these terminals by means of closing the lamp flashing contacts, Fig. 60, with the worm traveller as it reaches the end of the operation sequence flashes the lamp during the photographic period. For notes on the settings of the control panel to give satisfactory flashing values see discussion under "Lamp control for photographing", page 23.

The film-holder is balanced for the highest speeds using cut-film. When using roll films the balance is arranged only for the middle exposure of the 3 and 5 exposure film or paper. For the other exposure positions, the balance is slightly out at the first and last exposure, and becomes progressively better as the mid-exposure is approached. In the case of the V-104, which is a two exposure, film balance is arranged for the second exposure.

In the balanced positions the following weights and spools are required:

Parts Required for Balance		Roll Film & Paper Oscill. Exp.	
		E.K. V-122-6 ex.	3
S #937151		W S #937136	3
Weight	10.7 grams	W S #937137	3
		W S #937138	3
S #937152			
Weight	12.0 grams	E.K. V-104-6 ex.	2
		W S #491684	5
S #937153		W S #721899	5
Weight	15.0 grams	W S #721347	5
S #937154			
Weight	19.8 grams	E.K. V-122-10 ex.	5
		Cut-Film & Paper	
S #1000877 Two 5" Wooden spools weight	15 grams ea.	W S #937139	1
		W S #937140	1
		W S #937141	1
		W S #937142	1

The last item shows wooden spools required. These are dummy spools used only for dark room loading and are placed in the un-exposed spool positions. In this case, the balance weights (used only with roll film) are removed and the screw for holding them in place must be

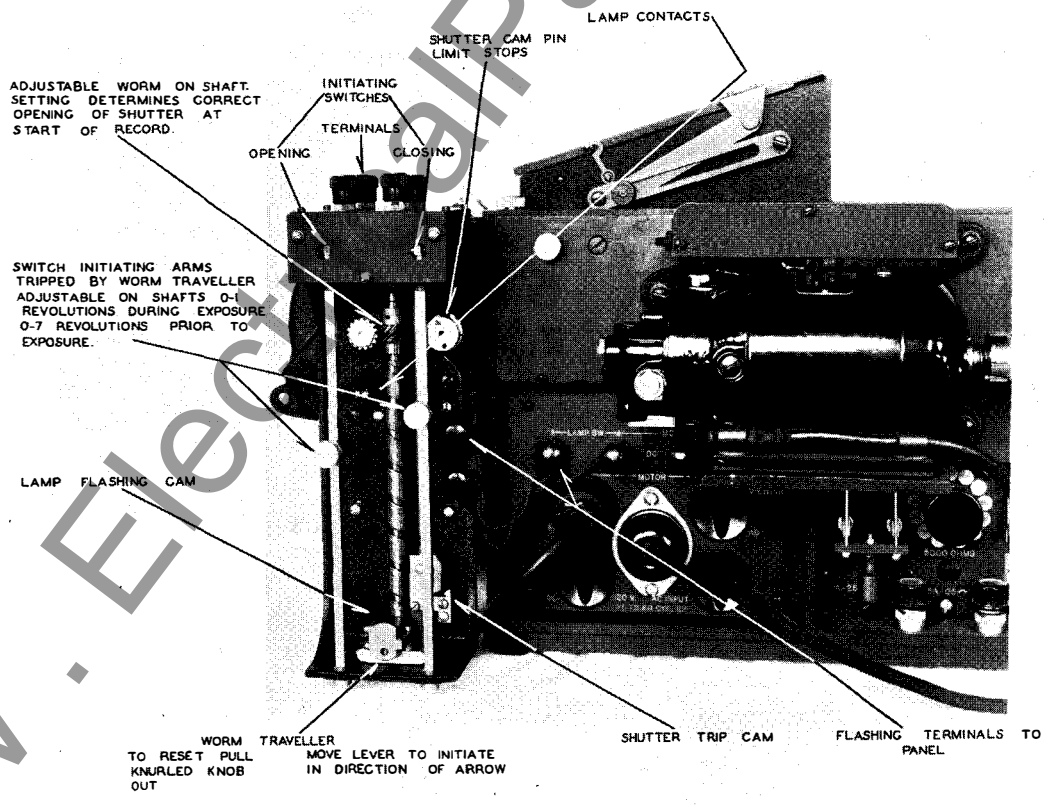


FIG. 60—SIDE VIEW OF DRUM TYPE FILM HOLDER SHOWING WORM TRIPPING MECHANISM.

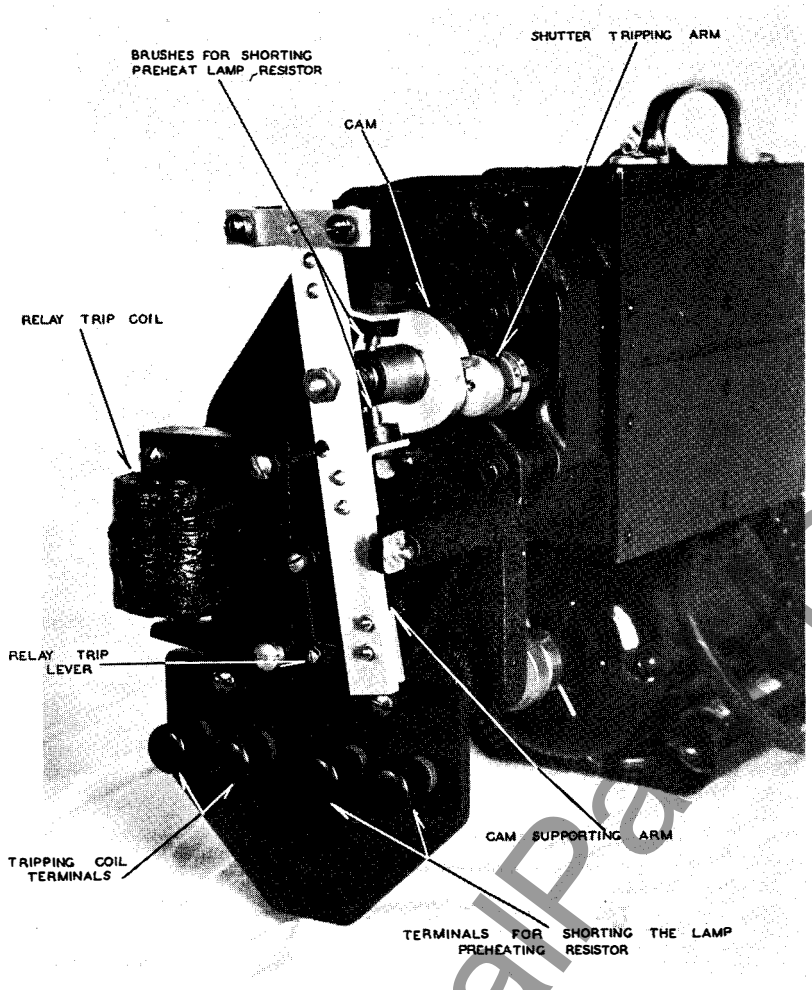


FIG. 61—SIDE VIEW OF DRUM TYPE FILM HOLDER SHOWING CAM TRIPPING MECHANISM.

left in its hole to keep balance. Also, this will prevent its being lost.

The film-holder is designed to work with all type PA Oscillographs, and can be adapted to Multi-Element use by means of adapter plates. Because it has a self-contained automatic shutter, no other type of shutter is necessary. The automatic shutter permits almost the full use of the drum for exposure 11″ out of a possible 12″ (the drum circumference).

Fig. 63 shows the spare parts included with this film-holder, also the extensions for changing from 5″ film to narrow $3\frac{21}{32}$″ film, and three extra belts, four balance weights, a key, and two dummy spools for dark room loading.

Fig. 62 shows the left side. The film wind-up knob, used only with daylight loading, is designed to advance the exposure and to tighten the film on the drum to prevent its flying off during exposure. In the "out" position, the film can be advanced; in the "in" position, the film can be locked in position. To release the knob in the locked or tightened position, it should be advanced slightly and pulled out at the same time.

The film speed to use is determined by the conditions of test, namely the type of phenomena to be investigated and the portion of the record it should occupy for analysis. Fig. 62 shows a stepped pulley arrangement with belt drive. For very slow speeds all three belts are used. For intermediate and high speeds only a single belt is required.

The following table of pulley ratios gives the speeds obtainable at full motor speed of 5000 R.P.M.

Pulley Diameter.			
Motor	**Drum**	**Belts**	**Speed R.P.M.***
$1\frac{5}{8}$″	$3\frac{1}{8}$″	1	2100∅
$3\frac{3}{4}$″	$\frac{3}{4}$″	1	2100∅
$\frac{7}{8}$″	$3\frac{3}{4}$″	1	1200
Using all Pulleys		3	120**

***Minimum speed approximately 1/5 of above values obtained by setting motor governor screw all the way in.**

****1⅝″ dia. motor pulley may be unlocked from 3¾″ dia. idler pulley with the screw shown in Fig. 62 to be used with the 3⅛″ dia. drum pulley which is to be unlocked from the drum to become an idler pulley by placing locking screw horizontal as shown in the Fig.**

Should the belts become too loose, the motor mounting screws may be extended and locked with the nuts shown in Fig. 62.

∅Max. recommended speeds for cut film only. Max. speed for roll film is 1500 R.P.M.

Fig. 60 shows the worm traveller which trips the shutter also the two trip switches "ON" and "OFF" set ready to trip. These switches, one to close a circuit the other to open a circuit are rated at 10 amps. 120 volts a-c., and 5 amps. d-c., may be set at a predetermined number of revolutions in advance of the shutter opening by moving them along the scale marked revolutions lead. Both switches must be advanced slightly as the scale indicates for high drum speeds.

Fig. 60 shows the trip mechanism for the shutter, the traveller and the lamp switches. The traveller moving

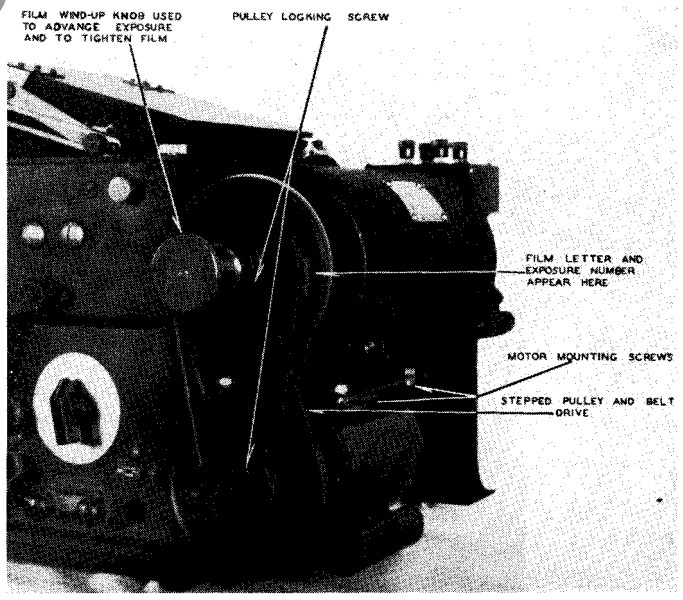


FIG. 62—FILM HOLDER IN OPERATING POSITION.

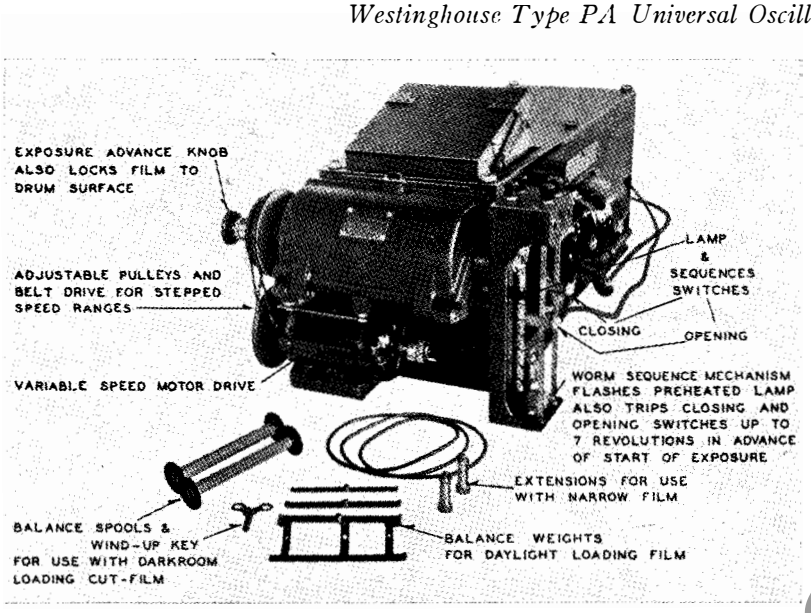


FIG. 63—ROTATING DRUM FILMHOLDER $\left\{\begin{matrix}3\frac{1}{4}'' \times 11'' \\ 5'' \times 11''\end{matrix}\right\}$ EXPOSURE FOR USE WITH DARK ROOM LOADING CUT FILM AND DAYLIGHT LOADING ROLL FILM—SPEEDS, 6 INCHES TO 35 FEET PER SECOND.

along the worm closes the lamp contacts in advance of the shutter opening which in turn shorts out a section of lamp preheat resistance as described for panel S#877043, page 23. The value of the preheat setting (see page 24 and dial in Fig. 35) must not be set in the danger zone for speeds much less than 1200 R.P.M., otherwise the lamp may burn out. Best photographic results are obtained from 10 volts d-c. supply for which the panel is calibrated, or from 115 V a-c. The input to the panel lamp terminals is shown connected to the lamp switch terminals on the panel.

Fig. 64 shows the drum closed as would be used for daylight loading films. In this case, the metal roll is placed in the holes further from the rubber roller. It may be moved from this position by inserting a pencil point into the holes and pressing back the spring shafts. For dark room loading the two rollers must be placed adjacent, and the little pawl on the right engaged in its ratchet gear. This prevents the film from pulling out and locks the 14″ cut strips in place similar to that of a wash ringer.

Fig. 65 shows the drum cover open. The spool in the cover is the exposed spool, and the one inside the drum is the unexposed spool. The film is wound up in the reverse manner from that of the unexposed portion, that is, away from the operator, on the top of the spool. It is loaded as follows: The cover open, the full spool is placed in the position shown, a portion of the leader about 15″ is pulled out. The cover is closed and the drum is rotated top towards the operator until the roller is reached. The cover is again opened and the leader is placed in the exposed spool and wound on top away from the operator until the taper of the leader just disappears from view (approx. one turn). The drum cover is closed and the two latches aligned with the white marks for the complete closed position. Also check to make sure the pawl, used for dark room loading only, is not in mesh with the ratchet gear or else the film register will not work.

The film-holder cover is now closed and the film register (the large knurled disc, see Fig. 62) is set on "W" for Westinghouse films and "C" for Commercial films. The film wind up knob in the out position advances the film to exposure 1, etc. Pushing it in and

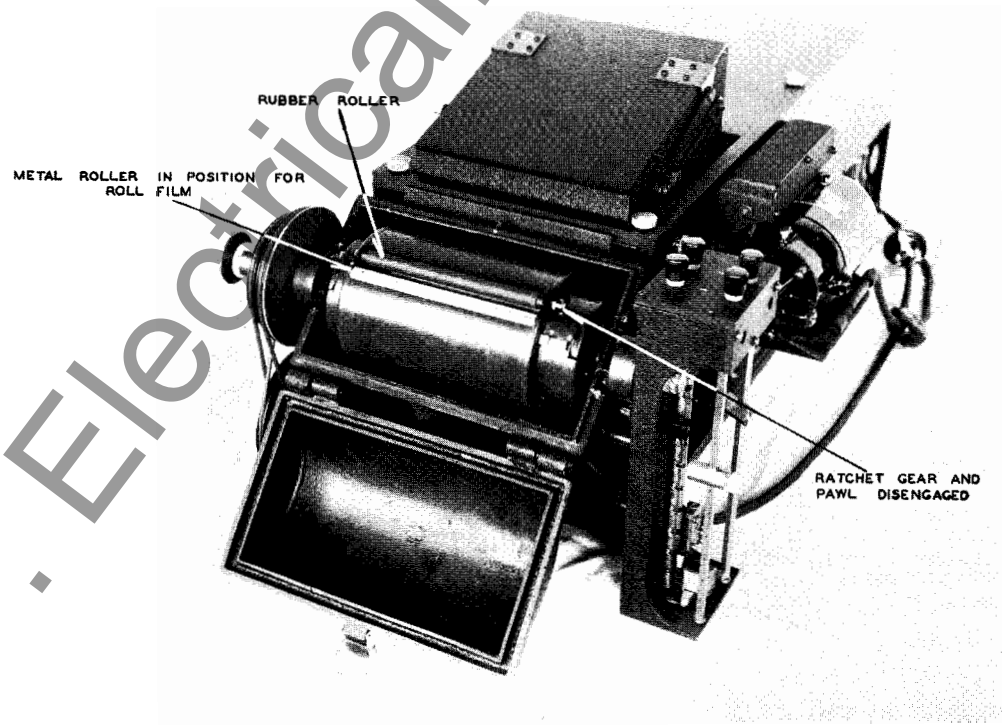


FIG. 64—DRUM CLOSED FOR DAYLIGHT LOADING FILMS.

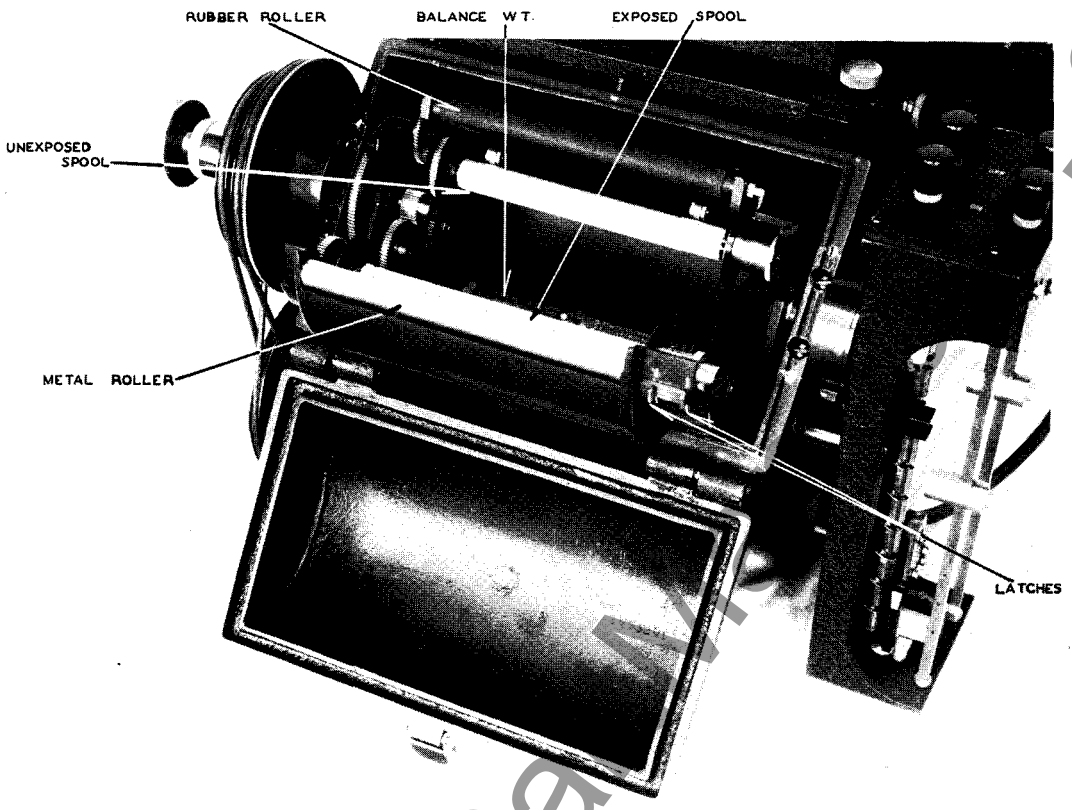


FIG. 65 - DRUM OPEN SHOWING POSITIONS OF EXPOSED AND UNEXPOSED SPOOLS.

advancing it locks the film on the drum.

Care should be used in the operation of the film-holder to avoid any unnecessary mechanical shocks as it can be damaged unless proper care is taken in its operation. The automatic shutter is set so as to be in the center of the slot and the front collar stop (Fig. 60) at the cam pin shaft is set for this position by means of the set screw in the collar. The back collar acts as an auxiliary stop to prevent chatter and is set by the position of the cam pin working against the cam surface. The cam may be moved back and forth on the traveller towards the cam pin by loosening the filister head machine screws holding it to the traveller. In the fully open position, .001″ to .002″ play should exist between the maximum rise of the cam surface and the cam pin. At the start of opening, the cam pin should just be tangent to the cam.

The start of the shutter opening must occur at the beginning of the exposure or when the metal roller is directly in front of the slot (rotation clockwise facing the worm side). This may be set correctly by loosening the gear on the worm shaft after which it may be moved with respect to the worm to give the desired condition.

To determine film speed, tachometers should be used and they may be placed in the center of the wind up knob, Fig. 62.

When using the cam tripping mechanism, Fig. 61, the sequence of operation is as follows: The circuit breaker or switch mechanism is connected in series with the tripping coil for the rated coil voltage according to the nameplate rating, marked "tripping coil terminals" in Fig. 61, the shorting preheat resistor terminals, panel S #877043, page 23, are connected to the "preheat lamp shorting terminals", Fig. 61. The film-holder is loaded with cut film or paper as has been previously explained for the full drum circumference. Fig. 61 shows the correct initial setting of the cam which must be set before loading the film-holder. The movable arm supporting the cam must lock the cam away from the friction wheel on the drum shaft by means of the relay "trip lever".

The drum is now set to rotate at a suitable film speed. The device to be tested closes the relay coil thereby tripping the cam arm which then moves forward to mesh with the friction wheel on the drum. Rotation will take place for one revolution of the drum and the

THE FOLLOWING IS A TABLE OF FILMS TO BE USED WITH THE FILMHOLDER

Description	Oscil. Exp.	Width	Length	Identification
Commercial Film E.K. V-122-6 ex.	3	3 31/32″	36 1/8″	S #937696 or E.K. No.
Commercial Film E.K. V-122-10 ex.	5	3 31/32″	62 1/8″	S #937697 or E.K. No.
Commercial Film with special leader E.K. V-104-6 ex.*	2	5″	28 1/8″	S #930648
Westinghouse Film	3	5″	39″	S #937137
Westinghouse Film	5	5″	66″	S #721899
Westinghouse Sensitized Paper	3	3 31/32″	39″	S #937156
Westinghouse Film	5	3 31/32″	66″	S #491684
Westinghouse Sensitized Paper	3	5″	39″	S #937138
Westinghouse Sensitized Paper	5	5″	66″	S #721347
Cut Film	1	5″	14″	S #937139
Cut Film	1	3 31/32″	14″	S #937140
Cut Sensitized Paper	1	5″	14″	S #937141
Cut Sensitized Paper	1	3 31/32″	14″	S #937142

*** In case of emergency the commercial film E.K. V-104-6 ex. may be used, but the first 1 inch of record on the first exposure will be fogged if loaded in daylight.**

FIG. 65-A.

cam will lock itself against the friction wheel. For the next operation the cam must be reset by moving the tripping arm towards the shutter, then pulling the cam outwards away from the film-holder, rotate it into the position shown in Fig. 61. At this point the tripping arm should lock the cam out of engagement by means of the relay trip lever.

For instructions on photographing, see page 45. Except note that in dark room loading, great care should be used in handling the film so as to avoid finger marks which will cause fogging. By setting the worm traveller at the end of its travel (adjacent to the worm gear) the shutter may be locked in the closed position. This will prevent its accidentally being opened thus making a fogged film.

NEON TIMER ATTACHMENT

Description

This timer consists of a tube type rectifier, a control circuit and a neon flashing tube. The control circuit is of the resistor capacitor type. This circuit is charged and discharged at a rate controlled by the frequency of the voltage source. The discharge takes place through the neon tube which causes it to flash with great intensity for a very short time interval. This short flash is focused by an optical system to the film to give sharp lines at right angles to the direction of film travel.

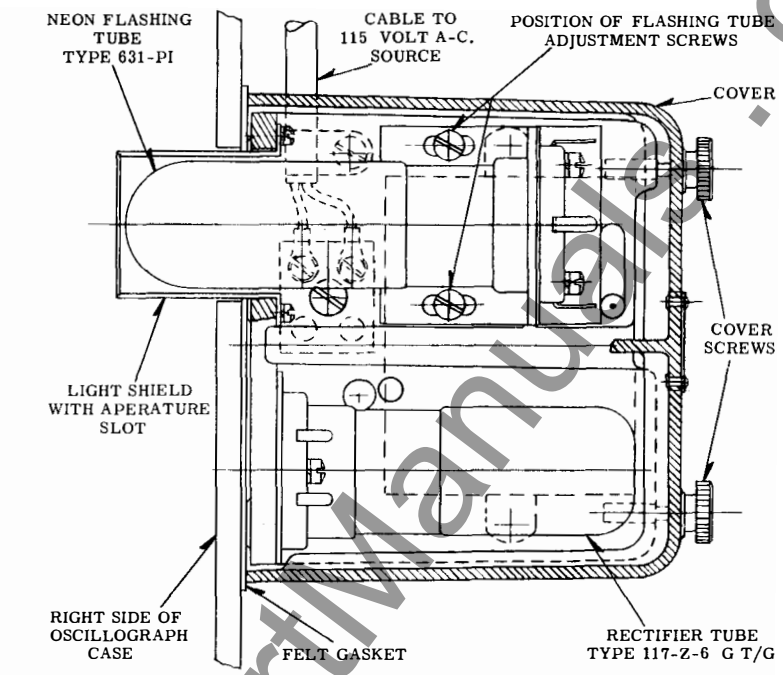


Fig. 66 Cross Section Views of Neon Timer

Operation

This procedure when the film is in motion, results in a time scale on the film. The time interval between lines is one cycle of the frequency which may be any 120 volt source from 25 to 1000 cycles. To get the best possible life from the flashing tube, it should only be energized during the exposure of the films. The inherent overall life of the tube is dependent on its number of flashes. Therefore, it is advisable to keep the timer energized only during the exposure of the film.

The timer is mounted on the right side of the oscillograph case facing the filmholder end, as shown in Fig. 66. In the latest type cases dummy hardware may be removed to permit its attachment when shipped separately. After installation the flashing tube should be moved to the extreme end of the slotted light shield as far as it will go by removing the timer cover and loosening the mounting screws on the tube base support. After this position is reached the tube should be backed off $\frac{1}{32}$ inch.

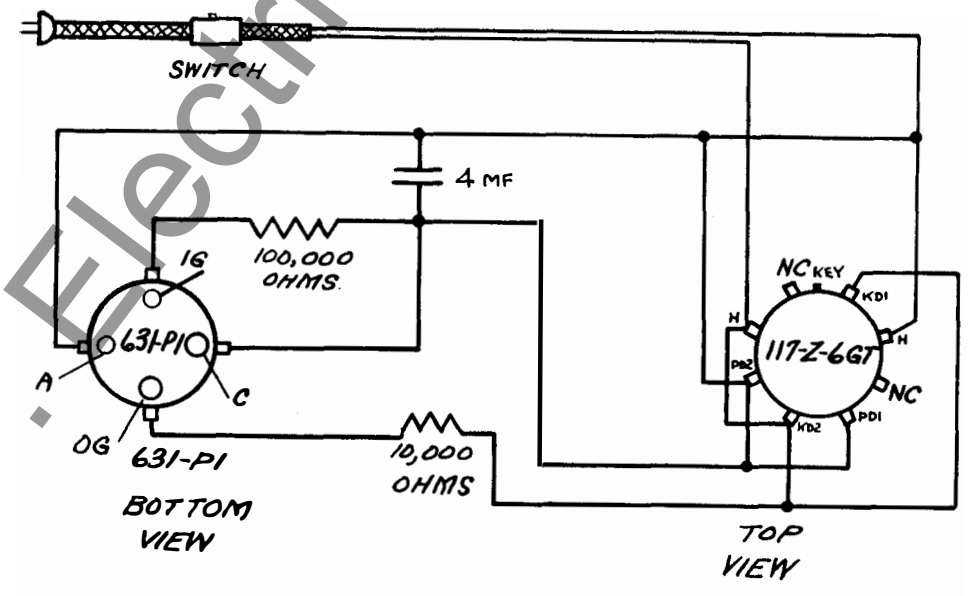


Fig. 66-A—Wiring Diagram of Neon Timer

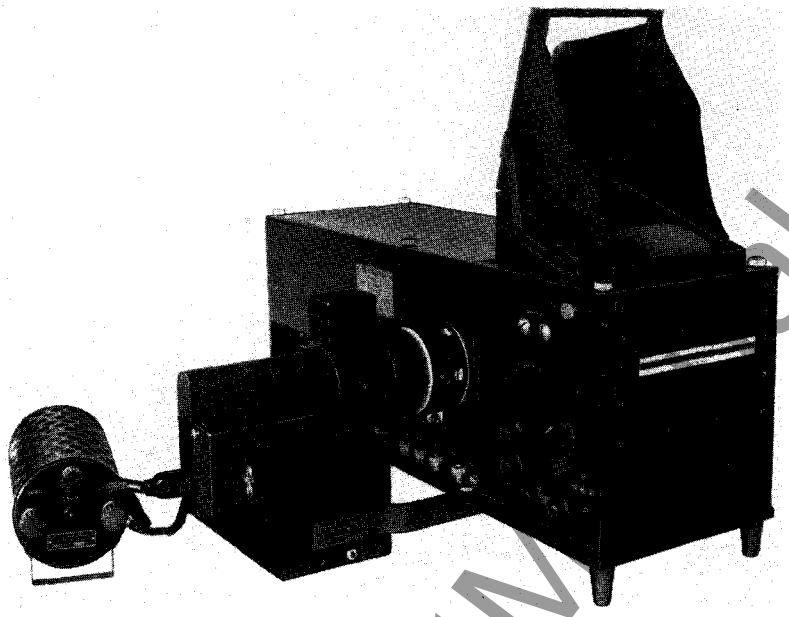


FIG. 66-B—OSCILLOGRAPH USING ARC LIGHT SOURCE AND SHOWING SPECIAL FEET.

Replace the cover and connect to the desired frequency source of 120 volts.

In case the timer ceases to function look for loose or defective tubes or defective circuit constants, Fig. 66-A. The neon flashing tube is Type 631-PI made by Hygrade Sylvania Corporation. The rectifier tube is type 117-Z-6 GT/G, either Hygrade or R.C.A.

NOTES ON OPERATION

Measurement of Current, Voltage and Watts, and Precautions to be Observed

General

The method of connecting the permanent magnet galvanometers is shown in Fig. 22-B. The watt elements connections are shown in Figs. 23-A, 26 and 30. Before connecting up any of the galvanometers, the instructions under the individual headings should be thoroughly understood.

Where extreme recording speeds are required it may be desirable to use an arc-lamp as indicated in Fig. 66-B. This assembly replaces the incandescent lamp assembly shown in Fig. 7.

Voltage Measurements

Resistances for voltage measurements should be of negligible inductance. Calibration can be made as shown in Fig. 22-B. All leads connecting the circuits to be tested to the oscillograph binding posts should be preferably of the twisted double conductor type. A good grade of lamp cord may be used for circuits up to 220 volts. Twisted leads are used to avoid inductive effects. As transient voltages may reach several times normal peak values, too much care cannot be paid to proper insulation.

The galvanometers are insulated to withstand 5,000 volts between elements but great care should be used to be sure all circuits are isolated. If the circuit being studied is grounded on one side, it is good practice to keep the rear binding post of each set connected to a fuse so that if it blows, the element and resistances will be at ground potential.

The safe voltage which can be directly applied to the oscillograph terminals depends on several factors: first, the skill and reliability of the operator; second, the amount of power available in the circuit; and third, the condition of insulation surfaces of the oscillograph. Faulty handling of the apparatus might result in serious injury to the operator.

In the measurement of high voltages, insulating potential transformers should be used wherever possible. Extra precautions must be used when considerable power backs the circuit. Protective fuses should be inserted between the circuit and the leads passing to the oscillograph. In d-c. testing the higher potential lead should be connected to the rear (fused) binding post of each element. It should be remembered that inductive kicks sometimes momentarily increase the voltage of the circuit a thousand per cent or more. The fuses to be connected in the leads should be relatively non-inductive and for the rating of the apparatus under test.

One method of measuring extremely high voltages with high external resistances is to use an external shunt resistance (R_P) across the vibrator or potential leads, (see Fig. 22-B). In this case one of the leads should be at or near ground potential. Also, all internal resistances should be cut out so that the shunt will take but a fraction of the total current. The capacity of the shunt must be such that if the element opened up, it could carry the current without materially increasing the voltage reaching the oscillograph. Water resistances through rubber tubes make effective controls for voltages running into the thousands. Distributed capacity, as well as inductance should be avoided for such measurements.

Current Measurements

Only non-inductive shunts should be used for oscillograph work and the resistances should be known in order to assist in setting the calibrations. See Fig. 34-D for ratings and Fig. 22-B for methods of calibration. In practice, the deflections are seldom figured except approximately. Calibrating instruments are always used when possible. Ordinarily the shunt e.m.f. drop is figured to see if it is reasonable and then the element is connected in with a large value of resistance which is later reduced to give the desired deflection. The shunt with leads is then calibrated with an ammeter.

Most commercial testing on d-c. power circuits requires shunts rated for the full line current. Standard ammeter shunts are of too low a millivolt drop rating and are too inductive to permit their use for this class of work.

On a-c. circuits shunts may be connected through current transformers. Again care should be taken to avoid high voltages by having one side of the secondary supplying the shunt at or near ground potential.

Watt Measurements

The general precautions mentioned for the permanent magnet galvanometers in keeping one side of the element at or near ground potential should be observed in the use of all watt galvanometers. The current coils are tested to withstand 1000 volts to ground momentarily so that they may be connected above ground if desired, though this procedure is not recommended.

The methods of calibration and connection are treated under the heading of each particular galvanometer.

Taking the Oscillogram

Taking of the oscillogram is the final operation. Before the oscillogram is finally taken, the following operations and adjustments must first be made:

1. After definitely knowing all the various indications required, a decision as to the galvanometers required with the vibrators of the proper characteristics should be made, see Fig. 9.
2. The arrangement of the position of the galvanometers and the vibrators in the oscillograph should be determined so that the recording beam on the oscillogram can be properly placed. (See discussion under "Marking of Oscillogram").
3. Adjustment of the galvanometer beams on the calibration window and viewing screen and the adjustment of the optical system to give maximum light intensity of the recording beam is required. **All lenses and prisms must be crystal clear.** (See discussion under "Optical Compartment".)
4. Connections of all the circuits to give the proper polarity and adjustment of all the circuit resistances to give the desired deflection on the oscillogram must be made. (See Fig. 22-B.)
5. Calibration of all the beam deflections in volts, amperes or watts per inch of beam deflection must be recorded. (See Fig. 22-B.)
6. Lastly, the taking of the record or oscillogram. (See the discussion under "Filmholders".)

Developing Films

Where no dark room is available, films may be developed in a tank-developer. Unless the oscillograms are slow-speed ones, or unless the light is especially intense, it is better to use a more contrastive developer. Double strength of developer may be used to advantage, but then care must be taken not to leave the film in the developer too long. To obtain the best results, the operator must experiment with different developer concentrations to find which will give the most contrastive oscillograms, when using the particular water, etc., of that locality. For ease and accuracy of interpretation, contrastive oscillograms are desirable. When developing films in a dark room, the operator has a chance to watch the process and control the development, so as to get the best results. Temperature and time are important.

Standard prepared package developer and fixing acid obtainable at any photographic supply (such as the Eastman Kodak M.Q. developing tubes) can be used very satisfactorily with good results. Development time five minutes at 68°F. The package directions are ordinarily followed; however, experimenting will prove better mixture combinations for any specific results. In general, more concentrated solutions will give more contrasting oscillograms.

This booklet assumes that the operator has knowledge of photographic developing.

Keep the film moving in the developer and be careful not to stain the film by improper handling, wash the film before placing it in the fixing bath. Hypo may be used or Eastman Kodak Acid Fixing Powder made up according to package directions. To obtain clear films do not use fixer after it has become discolored. Allow film to remain until clear approximately five minutes at 68°F.

Exposed film cartridges may be developed and printed by the film photographer provided they received a very good exposure (in the oscillograph), and, also, provided the photographer is warned not to cut the long exposures in two. In order to properly number and letter the films, it would be better to have the photographer return the films uncut.

The ideal temperature for storing photographic emulsions is 75°F. Dry Bulb, 61°F. Wet Bulb, at 44% Relative Humidity. The preceding notes on developing apply equally well to film or paper used with "W" oscillographs.

Marking of Oscillogram

In order that the films may have the most value for reference, each should have a number or letter or combination thereof to designate it; and, preferably, should have calibrations printed on the film so that they will show properly in the final photographic print. Some system should be adopted for numbering and calibrating the films. Also, it is usually found good practice to have some general scheme for arranging the zero lines and deflections from the elements. No hard-and-fast rule can be made.

The following is but a suggestion. When holding the oscillogram horizontally with record advancing from left to right, have the d-c. deflections extend upward or away from you, so as to have the zero of the scale near the foot of the oscillogram. To accomplish this, proper setting of the beams on the ground glass of the calibration window and the right polarities made to the galvanometers at the time of taking of the oscillogram should be made. In all the new filmholders the film or sensitized paper in the camera advances downward past the oscillograph opening where the galvanometer beams expose the film. When using sensitized paper, the record of No. 1 galvanometer beam (extreme left-hand galvanometer, see Fig. 5) will be at the foot of the oscillogram and the d-c. deflections are upward. On the ground glass of the calibration window the beam will be to the right, although with the film, the deflection must be to the left on the calibration window to obtain a similar appearing oscillogram on the final print, and the No. 1 galvanometer recording beam will be at the top of the oscillogram.

The oscillogram, if film, is printed in the usual way with the sensitized paper against the photographic side of the film, then the time component will extend from left to right, the lettering on the shiny side of the film, with pen and ink or other means if desired (sample print of an oscillogram is shown in Fig. 67). If the sensitized paper is used directly in the filmholder, the outstanding difference in the oscillogram is the white background with black lines, the element numbers are from bottom to top and the beam deflection on the oscillograph is from left to right so that the deflection on the record is from bottom to top.

In measuring beam deflections on the oscillogram a transparent scale is found very convenient. Or, with film, in making prints a transparent scale laid on the film will plainly show printed directly on the final oscillogram. If the same calibration is used for many films, a scale numbered in volts or amperes may be made on a piece of white paper and laid under and traced on each film. This scheme is particularly applicable to time scale where many films are run at the same speed.

When much work is to be done, it is convenient to construct a chart consisting of many lines converging to a point from equally spaced points on a perpendicular to the center line. Draw a line, on the film perpendicular to the zero line of the element to be scaled. Place the zero line on the film over the center line of the chart and then shift the film until the converging lines intersect the scale so as to give the proper intersections to correspond with the particular calibration in amperes per inch or volts per inch.

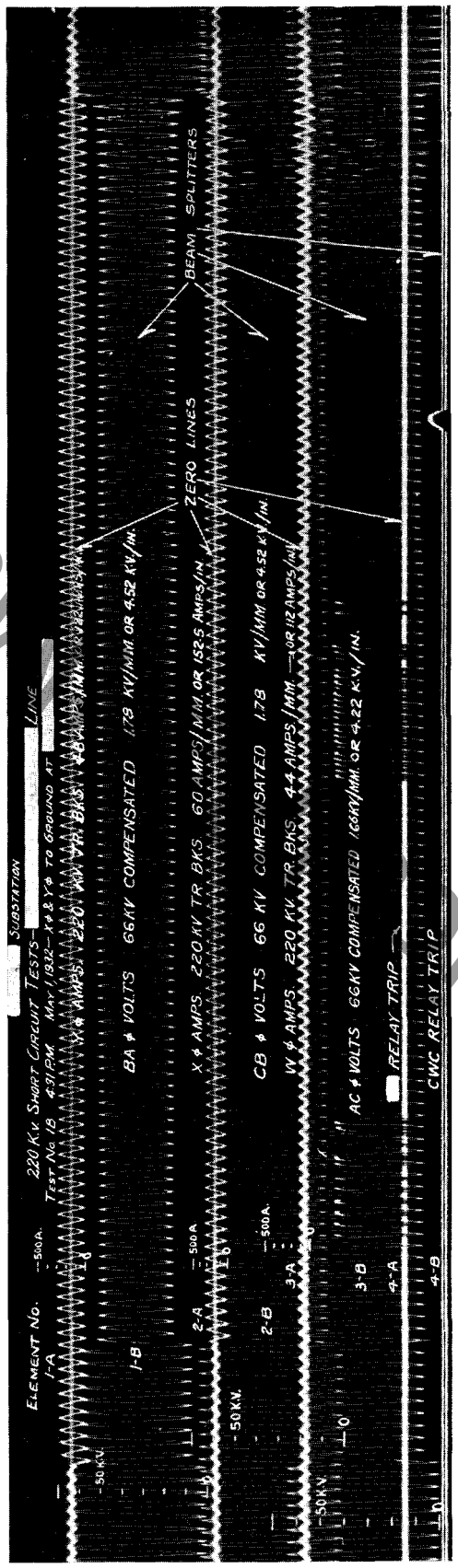


FIG. 67—SAMPLE OSCILLOGRAM TAKEN ON AN EIGHT-ELEMENT UNIVERSAL OSCILLOGRAPH HAVING FOUR BEAM SPLITTERS AND FOUR ZERO LINE-INDICATORS. THIS OSCILLOGRAM GIVES A GOOD EXAMPLE OF MARKING THE RECORD FOR FILING.

BIBLIOGRAPHY

1. Legg, Joseph W.
"The Electric Journal":
"Oscillography" Oct. 1927; "The Multi-Element Oscillography", Nov. 1927; "Transmission Line Studies", Dec. 1927; The Osiso "Phonoscope For the deaf", Aug. 1927; "The Osiso", July 1927; "A six-Element Portable Oscillograph", Mar. 1925; "The Osiso", Dec. 1924; "A Portable Oscillograph", Dec. 1920.
"A. I. E. E. Engineering Journal":
"The Six-Element Oscillograph, July 1920 and Feb. 1923; "Power Recording Apparatus", Sept. 1927.
2. Leyland, S. C.—"The Electric Journal"—"New Power Oscillograph is Automatic and Quick Acting", May 1931; also, "Viewing and Recording Simultaneously", Feb. 1932.
3. Thomander, V. S.—"The Journal of the Franklin Institute"; "Characteristics of the Oscillograph-Galvanometer", Jan. 1932.
4. V-S Thomander and Paul MacGahan, The widening field of oscillography "Instruments" July, 1935
5. Irwin, J. T.—A Text "Oscillographs", London Sir Isaac Pitman & Sons, Ltd., 1925.
6. Kennely, A. E.—Hunter, R. N. and Prior, A. A. Oscillographs and their Tests, Boston, Publication of the Massachusetts Institute of Technology, 1920
7. Hardy, Arthur C., "The Optical System of the Oscillograph and Similar Recording Instruments"—Reprint from the Journal of the Optical Society of America and Review of Scientific Instruments, Vol. 14, No. 6, June, 1927.
8. Symmetrical Coordinates
C. L. Fortescue, A.I.E.E. 1918, Vol. 37 Part 2, Page 1027.
9. New Sequence System of Polyphase Meters
R. D. Evans, Electrical World, 1923 Vol. 81, No. 6, Page 333.
10. Symmetrical Components—C. F. Wagner
R. D. Evans, Electric Journal March, April, June, July, 1928 September, December 1929
11. How the Positive Sequence Network Works
H. R. Stewart, Electric Journal June, 1929
12. The Application of Automatic Oscillographic Equipment for Power Systems
A. Dovjikov, Electric Journal May, 1929
13. Measurement of Symmetrical Components
A. P. Hayward, Electric Journal 1931

NEW AND REPLACEMENT STYLE LIST FOR THE PA UNIVERSAL OSCILLOGRAPH

Style	Title	Figure
	MAIN CASE	
877 036	Main Case for the "PA" Universal Oscillograph	4
	VIEWING ATTACHMENTS AND COVERS	
704 205	Plain Cover	
704 206	Cover for Calibration Window or for 4-sided polygon viewing	52
704 212	Simple Calibration Window with plain ground glass	3
877 029	Simple Calibration Window with calibrated ground glass (M. M. Scale)	3
930 704	Simple Calibration Window with calibrated ground glass (Inch Scale)	3
876 494	Complete 4-sided polygon viewing with 45° mirror and light-shield	
877 128	Complete simultaneous viewing with 115 volt A-C. or D-C. direct drive with cover for PA Universal Oscillograph only	2–3
877 129	Same as S # 877128 except with 6 volt D-C. drive	2–3
878 434	Cover for simultaneous viewing	
1003 771	Spare Viewing Motor complete with bracket 6 volts D-C. (Governor type)	
1003 772	Spare Viewing Motor complete with bracket—115 volts D-C. (Governor type)	
	PANELS	
	Laboratory Application	
877 043	115 volt A-C. or 6 to 10 volt D-C. lamp and motor supply panel	35–36
820 094	Half-length current and voltage resistance control panel	38
	Automatic Power Application	
877 042	Automatic panel plus heavy battery leads for 6 volt D-C. operation	40–41
820 093	Half-length positive or negative current phase-sequence network panel (for 60 cycles only)	
877 608	Half-length panel—same as S # 820093 except for 50 cycles	
1096 038	Half-length panel—same as S # 820093 except for 25 cycles	
704 222	Half-length current control panel (5 ampere shunts)	49
569 048	Full-length potential control panel (3 transformers for 120 to 0.6 volts—25 to 60 cycles)	
569 046	Half-length potential control panel (2 transformers for 120 to 0.6 volts—25 to 60 cycles)	
584 394	Half-length angle control panel	
	All Applications	
569 047	Half-length blank panel	

NEW AND REPLACEMENT STYLE LIST FOR THE PA UNIVERSAL OSCILLOGRAPH—Continued

Style	Title	Figure
	COMPLETE GALVANOMETERS	
877 119	Complete standard permanent magnet vertical galvanometer	8-11
877 120	Complete sensitive permanent magnet vertical galvanometer	8-23
877 121	Complete high-sensitive permanent magnet vertical galvanometer	8
877 122	Complete super-sensitive permanent magnet vertical galvanometer	8
877 123	Complete sensitive fin. permanent magnet vertical galvanometer	
877 124	Complete super-sensitive fin. permanent magnet vertical galvanometer	
877 125	Complete high-frequency permanent magnet vertical galvanometer	8
877 126	Complete twin permanent magnet vertical galvanometer	8-20-21
877 080	Complete single phase instantaneous watt vertical galvanometer	23
877 081	Complete single phase average watt vertical galvanometer	23
877 082	Complete polyphase instantaneous watt vertical galvanometer	25
877 083	Complete polyphase average watt vertical galvanometer	29
821 568	Complete ultra-sensitive 20,000 turns vertical galvanometer	31
1001 995	Complete standard horizontal galvanometer	10
1001 996	Complete sensitive horizontal galvanometer	10
1001 997	Complete high sensitive horizontal galvanometer	10
1001 998	Complete high frequency horizontal galvanometer	10
	GALVANOMETER PARTS—Vertical Vibrator Elements	
492 484	Standard vibrator element	11
492 485	Sensitive vibrator element	23
565 161	Sensitive fin. vibrator element	
577 707	High-sensitive vibrator element	
577 706	Super-sensitive vibrator element	
877 488	Super-fin. vibrator element	
573 785	Twin vibrator element	20-21
560 677	Polyphase instantaneous watt vibrator element	25
877 494	Ultra-sensitive vibrator element	31
652 256	Polyphase average watt vibrator element	29
492 487	Carrying case for vibrator element	
877 443	High-frequency vibrator element	
	VERTICAL GALVANOMETER WELLS	
877 483	Standard permanent magnet well complete	8
877 484	Twin permanent magnet well complete	8
877 485	Single phase watt well complete	23
877 486	Polyphase instantaneous watt well complete	25
877 487	Polyphase average watt well complete	29
877 496	Ultra-sensitive 20,000 turn well complete	31
	DAMPING FLUID AND FUSES—SEE FIG. 9	
	FILM HOLDERS—Complete Holders	
704 220	10 ft. film or sensitized paper holder, continuous, 6 volt D-C. motor drive with magnetic clutch for Automatic Power Application	52-53
704 219	Same as S # 704220 except without magnetic clutch	52
821 693	200 ft. film or sensitized paper holder, continuous, 6 volt D-C. motor drive with magnetic clutch and extra lower magazine (for power application)	54-55-56
877 132	Same as S # 821693 except without magnetic clutch	
877 130	10 ft. film or sensitized paper holder, continuous, 115 volt universal motor drive with an adjustable governor speed control of 15 to 1 ratio	
830 614	200 ft. film or sensitized paper holder, continuous, 6 volt D-C. governor motor drive with extra lower magazine—no clutch—complete	56
930 792	200 ft. film or sensitized paper holder, 115 volt A-C—D-C governor motor drive, extra lower magazine	
930 793	10 ft. film or sensitized paper holder, 6 volt D-C. variable speed motor	
930 614	200 ft. film or sensitized paper holder, 6 volt D-C. variable speed motor extra lower magazine	
934 010	Drum Film Holder (5″ x 11″) or ($3\frac{11}{32}$″ x 11″) record, 115 volt universal governor motor drive	63
934 009	Same as S # 934010 except with 6 volt D-C. variable speed motor	63

NEW AND REPLACEMENT STYLE LIST FOR THE PA UNIVERSAL OSCILLOGRAPH—Continued

Style	Title	Figure
	PARTS FOR HOLDERS	
877 070	6 volt D-C. motor for film holders and with governor control	
877 069	115 volt universal motor for film holders and with governor control	
773 274	6 volt shunt motor for 10 and 200 ft. holders for automatic power application	52
1157 091	Similar S # 773274 except with special brush contact on shaft end for clutch	
1158 857	Shaft Contact Pin for Motor S# 1157091	
704 218	Magnetic clutch for motor S # 773274 and S# 1157091	52-58-58A
877 041	Pinion and plate for 10 ft. holder and motor S # 773274	
877 073	Pinion and plate for 10 ft. holder and governor motor	
877 131	Pinion worm for 200 ft. holder and motor S # 773274	
821 686	Extra lower magazine for 200 ft. holder	54
877 072	Condensor and resistor parts for universal motor, 115 Volt Service	
934 139	Magnetic Clutch complete 6 volts D-C.—for 200 ft. holder	55
722 798	Clutch Contact Pin for 10 ft. Filmholders	
10.59 891	Clutch Contact Pin for 200 ft. Filmholders	
1268 065	Clutch Contact Pin for Tandem Operation	
934 006	6 volt D-C. motor, governor type, for 5″ Drum Film Holder, Fits 10 ft. and 200 ft. holders	
934 005	115 volt A-C. motor, governor type, for 5″ Drum Film Holder, Fits 10 ft. and 200 ft. holders	
1003 773	Remote control tripping mechanism	61
1009 730	Worm Tripping Mechanism	63
937 164	15½″ long, ⅛″ diameter belt for 5″ Drum Film holder	63
	MISCELLANEOUS PARTS FOR PHOTOGRAPHING	
821 687	Pulley and Countershaft attachment	55
877 079	Magnetic shutter with leads (automatic applications 6 volt D-C.)	59
703 509	Short rubber belts for 10 ft. film holder rollers	
723 219	Film spool pivots for 10 ft. holder	53
820 870	Empty film spool for 200 ft. holder	
821 695	Spring to clamp end of film to empty spool for 200 ft. holder	
821 690	Operation indicator 6 volts D-C. for 200 ft. holder and panel S # 877042	54
821 699	Spring belt drive for reroll spool for 200 ft. holder	54
838 140	Adapter plate for Osiso film holders and polygon on PA	
836 284	Adapter plate for PA holders on multi-element oscillograph	
1267 259	Operation Indicator, 115 volts A-C., for use with 200 ft. holder and panel S # 877043	
1267 260	Operation Indicator, 6 volts D-C., for use with 200 ft. holder and panel S # 877043	
1268 066	Coupling Shaft for tandem operation of oscillographs	57A
	MISCELLANEOUS PARTS—General	
930 416	Mobile table	
876 692	Endless rubber non-stretchable belt 28 inches long	
518 024	Endless leather belt 40 inches long	
821 360	Westinghouse Lubricant Vaseline Tube for greasing of film holders	
930 298	Zero line indicator for PA universal	
719 387	Beam splitter	59
492 486	Spare parts box	
M5 612	Super LAX Grease No. 4X for ball bearings on 6V motors S # 773274 and S # 1157091	
820 154	External current shunt .5 to 1.0 amperes	
491 700	External current shunt 2.5 to 10. amperes	
819 940	External current shunt 12.5 to 25. amperes	
492 497	External current shunt 20. to 1000 amperes	34
***	Extra motors on panel base with control and step pulley drive may be obtained.	53-B
1001 972	Adjustable Slit Assembly for optical box	
1001 973	Prism Assembly for optical box	
878 371	Optical Adjusting tool for slits and prisms	
1268 931	Neon Timer Attachment	66
	Rectifier Tube for Neon Timer 117-Z—6 GT/G (Hygrade Sylvania or equivalent)	66
	Flashing Tube for Neon Timer 631 PI (Hygrade Sylvania or equivalent)	66
1059 584	Arc Lamp	66-B
971 502	Rectox Battery Charger	Page 24
578 137	DC to AC Inverter	Page 24
837 265	Type SG Relay	Page 24
724 758	Battery cable (approx. 5 ft.) for 6-10 volts D-C. service	Page 24
1202 179	Spencer thermostat for panel S # 877042-C	Page 27

NEW AND REPLACEMENT STYLE LIST FOR THE PA UNIVERSAL OSCILLOGRAPH—Continued

Style	Title	Figure
	GALVANOMETER PARTS	
930 376	30 in. of polyphase average value watt element suspension ribbon	
439 224	30 in. of standard ribbon on spool	
439 225	30 in. of sensitive ribbon on spool	
577 709	30 in. of high or super-sensitive ribbon on spool	
594 650	30 in. of high-frequency ribbon on spool	
439 226	One standard mirror in bottle	
439 227	One sensitive mirror in bottle	
577 708	One high or super-sensitive mirror in bottle	
439 228	Mirror cement in bottle	
1001 984	Galvanometer lens window—horizontal	10
877 049	Galvanometer lens window—vertical	8
877 133	Gasket for oil seal on galvanometers	
559 753	3 standard vibrator mirrors in box	
559 754	3 sensitive vibrator mirrors in box	
594 186	3 high or super-sensitive mirrors in box	
559 755	Complete metal pill box for vibrator ribbon	
559 756	Complete metal pill box for vibrator mirrors	
1003 735	Gasket for element frame—Horizontal Galvanometer	
1003 734	Gasket for element top—Horizontal Galvanometer	
1001 816	Gasket between well and top plate of Vertical Galvanometers	
718 723	Adjusting Pinion for Vertical Galvanometers	11
1003 428	Adjusting Pinion for Horizontal Galvanometers	10
1001 999	Adjustable Mirror Assembly, complete for Horizontal Galvanometers	10

LAMPS

#35-C	Mazda lamp #35-C—Used in slow down circuit, panel S #877042, 2.4 Volts, 0.8 Amp	40
#1000	32-32 C.P. Mazda lamp—Used in panel S #877042 for Shutter and Clutch 6-8 Volts	41
#1129	21 C.P. Mazda lamp for optical system 6-8 Volts	7
#1133	32 C.P. Mazda lamp for optical system 6-8 Volts	7
#1183	50 C.P. Mazda lamp for optical system 6-8 Volts	7

SENSITIZED PAPER AND FILM FOR LONG FILM HOLDERS, 5 INCHES WIDE

		Exposures	Minimum Quantity To Be Ordered
721 347	66 in. Roll of Sensitized Paper	Any	24
721 348	10 ft. Roll of Sensitized Paper	Any	24
821 694	200 ft. Roll of Sensitized Paper	Any	8
930 648	28 in. Roll of Film	Any	12
721 899	66 in. Roll of Film	Any	24
682 184	10 ft. Roll of Film	Any	12
821 691	200 ft. Roll of Film	Any	7

SENSITIZED PAPER AND FILM FOR ROTATING DRUM HOLDER

Roll Film

937 696	36 in. Roll Film 3 21/32 in. Wide	3	12
937 697	62 in. Roll Film 3 21/32 in. Wide	5	12
930 648	28 in. Roll Film 5 in. Wide	2	12
721 899	66 in. Roll Film 5 in. Wide	5	24

Roll Paper

937 136	39 in. Roll Paper 3 21/32 in. Wide	3	24
937 138	39 in. Roll Paper 5 in. Wide	3	24
721 347	66 in. Roll Paper 5 in. Wide	5	24

Cut Film and Paper

937 139	14 in. Strip Film 5 in. Wide	1	1 doz. sheets
937 141	14 in. Strip Paper 5 in. Wide	1	1 doz. sheets